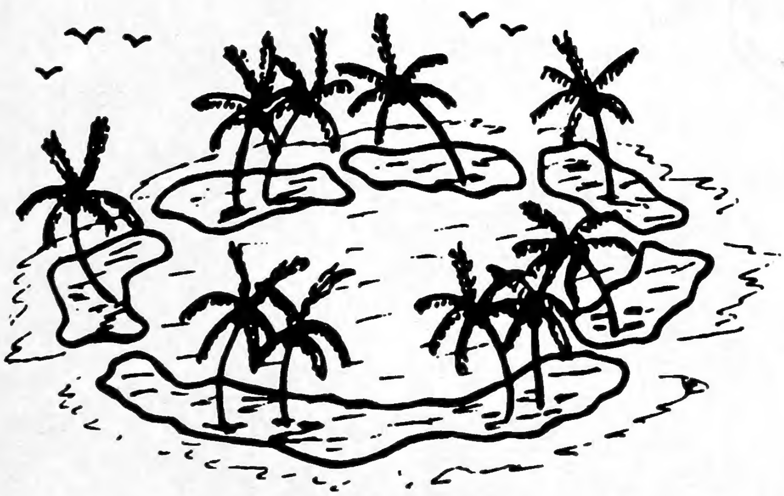
Nos. 293-305 August 1987

ATOLL RESEARCH BULLETIN

293. *Introduction to Marie-Hélène Sachet Commemorative Issue* by various authors
294. *Flora of Maupiti, Society Islands* by F. Raymond Fosberg and Marie-Hélène Sachet
295. *Flora of the Gilbert Islands, Kiribati, Checklist* by F. Raymond Fosberg and Marie-Hélène Sachet
296. *Plants of Kiribati: A Listing and Analysis of Vernacular Names* by R. R. Thaman
297. *Rurutu Reconsidered: The Development of Makatea Topography in the Austral Islands* by D. R. Stoddart and T. Spencer
298. *Biology of Cook Islands Bivalves, Part I. Heterodont Families* by Gustav Paulay
299. *The Seaward Margin of Makatea, an Uplifted Carbonate Island (Tuamotus, Central Pacific)* by L. F. Montaggioni, C. Gabrie, O. Naim, C. Payri, G. Richard, B. Salvat
300. *Recent Changes in the Avifauna of Makatea Island (Tuamotus, Central Pacific)* by Jean-Claude Thibault and Isabelle Guyot
301. *Le Zooplancton du Lagon de Clipperton* by J.-P. Renon
302. *Dominant Macrophyte Standing Stocks, Productivity and Community Structure on a Belizean Barrier Reef* by M. M. Littler, P. R. Taylor, D. S. Littler, R. H. Sims and J. N. Norris
303. *Annotated Checklist of the Gorgonacea from Martinique and Guadeloupe Islands (F.W.I.)* by Philippot Vèronique
304. *Status of the Red-Footed Booby Colony on Little Cayman Island* by Roger B. Clapp
305. *Potential Fisheries Yield of a Moorea Fringing Reef (French Polynesia) by the Analysis of Three Dominant Fishes* by Rene Galzin



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ATOLL RESEARCH BULLETIN AUGUST 1987

NO. 293-305

293. INTRODUCTION TO MARIE-HELENE SACHET COMMEMORATIVE ISSUE
BY VARIOUS AUTHORS

294. FLORA OF MAUPITI, SOCIETY ISLANDS
BY F. RAYMOND FOSBERG AND MARIE-HELENE SACHET

295. FLORA OF THE GILBERT ISLANDS, KIRIBATI, CHECKLIST
BY F. RAYMOND FOSBERG AND MARIE-HELENE SACHET

296. PLANTS OF KIRIBATI: A LISTING AND ANALYSIS OF VERNACULAR NAMES
BY R. R. THAMAN

297. RURUTU RECONSIDERED: THE DEVELOPMENT OF MAKATEA TOPOGRAPHY IN THE AUSTRAL ISLANDS
BY D. R. STODDART AND T. SPENCER

298. BIOLOGY OF COOK ISLANDS BIVALVES, PART I. HETERODONT FAMILIES
BY GUSTAV PAULAY

299. THE SEAWARD MARGIN OF MAKATEA, AN UPLIFTED CARBONATE ISLAND (TUAMOTUS, CENTRAL PACIFIC)
BY L. F. MONTAGGIONI, C. GABRIE, O. NAIM, C. PAYRI, G. RICHARD, B. SALVAT

300. RECENT CHANGES IN THE AVIFAUNA OF MAKATEA ISLAND (TUAMOTUS, CENTRAL PACIFIC)
BY JEAN-CLAUDE THIBAULT AND ISABELLE GUYOT

301. LE ZOOPLANCTON DU LAGON DE CLIPPERTON
BY J.-P. RENON

302. DOMINANT MACROPHYTE STANDING STOCKS, PRODUCTIVITY AND COMMUNITY STRUCTURE ON A BELIZEAN BARRIER REEF
BY M. M. LITTLER, P. R. TAYLOR, D. S. LITTLER, R. H. SIMS AND J. N. NORRIS

303. ANNOTATED CHECKLIST OF THE GORGONACEA FROM MARTINIQUE AND GUADELOUPE ISLANDS (F. W. I.)
BY PHILIPPOT VERONIQUE

304. STATUS OF THE RED-FOOTED BOOBY COLONY ON LITTLE CAYMAN ISLAND
BY ROGER B. CLAPP

305. POTENTIAL FISHERIES YIELD OF A MOOREA FRINGING REEF (FRENCH POLYNESIA) BY THE ANALYSIS OF THREE DOMINANT FISHES
BY RENE GALZIN

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Articles submitted for publication in the Atoll Research Bulletin should be original papers in a format similar to that found in recent issues of the Bulletin. First drafts of manuscripts should be typewritten double spaced. After the manuscript has been reviewed and accepted, the author will be provided with a page format with which to prepare a single-spaced camera-ready copy of the manuscript.

Biographical sketch of

Marie-Hélène Sachet, 1922-1986

Dr. Marie-Hélène Sachet, for many years an Associate Curator of Botany at the U.S. National Museum, Smithsonian Institution, passed away, after a short illness, on July 19, 1986, at the Capitol Hill Hospital, Washington, D.C.

Dr. Sachet was born on April 19, 1922 at Moulins (Alliers), France. Her parents were science teachers in the Moulins school system, where Marie-Hélène received her primary and secondary education. Her direction toward botany was largely due to her professor at the University of Montpellier, Dr. Louis Emberger. After graduating from Montpellier she did graduate studies in geology at the University of Paris, later becoming a research assistant to Professor G. Mangenot of the university, working in cytology and fiber structure. She spent the year 1947 in the U.S. at Smith College as an assistant in the Datura studies of Professor A. F. Blakeslee and Dr. Sofia Satina, then returning to France, to work again with Prof. Mangenot.

In 1949 she accepted a position as research assistant to F. R. Fosberg at Catholic University of America. Later, she moved with Dr. Fosberg to the U.S. Geological Survey, with half-time at the Pacific Science Board of the National Academy of Sciences-National Research Council. She spent 15 years at these two institutions, working on the vegetation and flora of Micronesia and other Pacific Islands. During this time, after participating in a Scripps Institution of Oceanography expedition to Clipperton Island, eastern Pacific, she earned a Ph.D. at Montpellier, under Prof. Emberger, submitting as a thesis a comprehensive study of the natural history of Clipperton Island.

During this period, also, she with Dr. Fosberg assembled a large volume on Island Bibliographies (1955), with a supplement later (1971), published by the National Academy of Sciences-National Research Council. Over the course of these years she became a recognized authority on coral atolls, and on the floras, ecology and geography of the Pacific oceanic islands. From 1951 until her death she was co-editor of the Atoll Research Bulletin, the 292 numbers of which provides singular evidence of her diligence and high standards.

She moved in 1966 with Dr. Fosberg to the Smithsonian Institution, where she worked for the rest of her life, contributing materially to making it a leading center for Pacific and Indian Ocean island botany. She devoted unceasing energy to the administration of the Ceylon Flora Project, and made substantial progress toward floras of the Marquesas and other groups of islands in French Polynesia, working closely on these with the Laboratoire de Phanerogamie, Museum d'Histoire Naturelle, Paris. With her death, these floras remain to be completed by others.

She participated in Pacific Science Congresses in 1957, 1961, 1966, 1971, 1975 and 1983, in International Botanical Congresses in 1954, 1959, 1964, 1969, 1975 and 1981, and in International Coral Reef Congresses in 1977 and 1985.

She made substantial contributions to island ecology, floristics and biogeography, in addition to being unfailingly helpful to promising younger scientists interested in work on island biology and geography.

Her publications are listed below in this issue.

MARIE-HELENE SACHET
1922 - 1986

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BY

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CONTENTS

page

Marie-Hélène Sachet: Islands, Atolls and Reefs
By F. R. Fosberg. . . . . 1.

Tributes to Marie-Hélène Sachet
By various authors . . . . 8.

Recent activities of the Micronesian Research Center (MARC)
By Hiro Kurashina, D. Ballendorf, K. Carriveau, M. Driver,
B. Karolle, T. McGrath and A. Williams . . . . 11.

List of Publications of Marie-Hélène Sachet . . . . 15.

List of Atoll Research Bulletin Titles issued
under Marie-Hélène Sachet's co-editorship . . . . 22.

MARIE-HELENE SACHET : ISLANDS, ATOLLS AND REEFS

By

F.R. Fosberg

Dr. Marie-Hélène Sachet's name will always be associated with studies of tropical islands, perhaps more especially with the terrestrial aspects of coral islands (the above water portions of present-day coral reefs). Few people have ever amassed knowledge comparable with what she had of this pan-tropical phenomenon, the coral-island ecosystem. By her bibliographic studies she had a vast familiarity with the works and ideas of a distinguished line of investigators in this field. One may mention the Forsters, who first differentiated "high" and "low" islands, the latter being most of the coral islands; Chamisso, who made perhaps the first rather detailed scientific observations of coral atolls, with Kotzebue on the voyage of the Rurik; Darwin, whose brillianntly conceived subsidence theory explained the ring-like geography of atolls; Alexander Agassiz, J. Stanley Gardiner and W. M. Davis, who described and interpreted coral atoll and reef geography on a worldwide scale; Mayor, Setchell, and Ladd and Hoffmeister who studied in unprecedented detail the nature and formation of reefs. She studied the results of the German South Sea Expedition, the Whitney Expedition, Mangarevan Expedition and the Micronesian Economic Survey, all of which visited numerous atolls in the first half of this century, and the contemporaneous incredibly detailed investigations of Bikini and neighboring Marshall Islands. Familiarity with these and numerous other published sources of information gave her an incredibly rich background for her own studies and for her unfailing help and support for other workers, particularly for promising younger people entering the field.

Her activities have been inextricably entwined with my own and those of David R. Stoddart, so that her major contributions have tended to be overshadowed or unappreciated. An account of a long term project, investigating the geography and terrestrial ecology of coral islands may serve to explain and commemorate Marie-Hélène's role in the fascinating field of island studies, as well as, incidentally, to point up some aspects of long-term interdisciplinary scientific studies.

Marie-Hélène Sachet came in 1949 from an obscure position in a cytology Project in the University of Paris, to help me in what we informally called the Pacific Vegetation Project, funded at that time by the U.S. Army Quartermaster General's Office, and housed at the Catholic University of America. The official objective was to establish the feasibility of using vegetation as an indicator of other environmental characteristics and conditions in the Pacific Islands, especially by interpretation of air-photos. This project was not particularly centered on coral-islands, and it must be kept in mind that our studies of atolls were, and still are, a component of broader floristic, taxonomic, ecologic, biogeographic, and vegetation investigations of tropical islands, generally. Our project was in 1951 transferred to the U.S. Geological Survey, where we became Pacific Islands vegetation experts for their Military Geology Branch. We stayed there for 15 years, working closely, also, with the Pacific Science Board (PSB) of the National Academy of Sciences-National Research Council.

In 1949 the South Pacific Commission (SPC) Research Council had enlisted the cooperation of the Pacific Science Board, under Harold J. Coolidge, in a Project on economic welfare of the peoples living on coral atolls, asking especially for help in compiling published information on atolls. Thus was born a major, long-term multidisciplinary and interdisciplinary study of coral islands and the reefs that

become islands when their surfaces become exposed above the sea surface.

This got underway, supported by the Office of Naval Research, Geography Branch, in 1950, and we were much involved with it from the first, handling the bibliographic work requested by the SPC, and consulting in the organizing and carrying out of five major detailed studies of representative atolls. This, of course, fit right in with our Pacific Island vegetation studies for the U.S. Geological Survey, where our first major enterprise was an extensive study of the Northern Marshall Atolls.

Marie-Hélène's first seven years were mostly taken up by a massive bibliographic study of island literature, extracting and organizing information, producing a large volume, Island Bibliographies, published by the National Academy of Sciences-National Research Council. At the same time she was involved with handling a vast inflow of specimens and field data, never seeing a coral island herself until 1957. By this time, however, she had become a major source of information to almost everyone concerned with tropical islands, especially atolls. During the five years of large-scale field work in the PSB Coral Atoll Program she was the source of background information and specific details for most of the personnel involved, and saw to the publication of their reports. At the beginning of this program it was decided that the reports should not be buried in the U.S. Navy files, but should be available to everyone seriously interested in coral islands and reefs. The expedition reports and related papers were duplicated for the Office of Naval Research, and a large over-run was made (at least we thought it was large) and distributed to a selected list of interested workers and institutional libraries. For easy reference we named it the Atoll Research Bulletin, and it was issued by the Pacific Science Board. We were joint editors, but Marie-Hélène did most of the work, throughout its history through number 292, the one just preceding this one. Her standards became more meticulous as the journal grew in importance, to become, in the words of more than a few users, the most important single source of information on atolls and reefs. No one not immediately involved, can have an adequate idea of the amount of detailed work that she put into this enterprise for 36 years, mostly over and above her proper job. The Atoll Research Bulletin, familiarly known as ARB, will be her lasting monument, in addition to her very impressive list of publications, notably the Island Bibliographies volume (1955) and its Supplement (1971) (see appended list).

The component of our program of island studies that from the first was Marie-Hélène's special interest was the terrestrial ecology of coral atolls. It was after World War II that the science of ecology began to mature to the point where its proponents started to realize that the organisms, the environment, the cycles, the interrelations, and the processes they were studying are all components of functioning systems. The term ecosystem was coined by Tansley in the 1930's, but never much used by him, and had, until mid-century, not become familiar, even to ecologists. About that time some ecologists began to refer to their science as the study of ecosystems, and about the time this was coming about, the incredible complexity of these systems was becoming apparent. How to gather, accumulate, and deal with the myriads of components and processes in an ecosystem became a major problem. Field naturalists, over years of observation, could develop an intuitive concept of the nature they were immersed in, but to record and analyze, and integrate such an enormous body of data into an understanding was an unmet challenge. Inklings of a way to go were apparent, but not generally recognized, in the relative successes of studies of extreme simplified ecosystems such as deserts and the the arctic. The continental tropical systems, culminating in the overwhelming complexity of the lowland tropical rain-forest seemed too much for the human mind. Islands, which had given vital clues to Darwin and Wallace, were obviously simpler than continents, but still defied the relatively few investigators that chose to study them. The multiplicity of habitats and micro-habitats on a high island in the rainy tropics, and even in the relatively few such islands in the dry tropics, presented such a set of variables, even in the few parameters that could be readily studied, that there seemed no way to handle or comprehend them, let alone compare their complexities from island to island.

Our studies of Pacific island vegetation, backed up by my own previous explorations of Polynesia

and Micronesia, suggested an approach that seemed worth trying.

Low coral islands or atolls presented a situation where the parent rock was all limestone of organic origin, varying in texture and in a very minor degree in chemistry. Compared with most other situations this was practical uniformity. The almost flat terrain, seldom more than 2 or 3 meters of relief, eliminated most of the variability due to altitude. The location of these islands in or very near the Tropical Zone and proximity to the ocean reduced temperature variation to a restricted range of warm temperatures. The biota was known to be impoverished. The pH was thought to be uniformly 7 to 7.5.

This left the principal variables to be moisture, wind, insolation, and salinity, all readily measurable. One might say the situation was about as near a laboratory arrangement as could be found in nature. Another advantage was the existence of a few slightly to well elevated atolls or limestone platforms, well scattered through the atoll regions of the three oceans. These would make it possible to assess the effects of the lack of relief.

Compared with continental, or even high-island ecology, this seemed to be simplicity itself. We thought that even the pertinent literature would comprise but a relatively small number of books and articles. How wrong we turned out to be on both these counts!

At the time of the South Pacific Commission request to the Pacific Science Board for help with coral atoll literature we had already started to collect and study the literature on Pacific Island botany and ecology, especially vegetation. This was easily broadened to include a focus on everything about coral islands that could possibly have a bearing on their land ecology, a subject that soon became fascinating to Marie-Hélène, a preoccupation that lasted throughout her career.

At the same time, a decision was made in the PSB to not be limited to compilation of data from literature, but to study atoll ecology and topics with a bearing on it actively in the field. A proposal was made to the Geography Branch of the Office of Naval Research to support studies of selected atolls in depth. This was accepted, planned for at least five years, with a major, multidisciplinary expedition to one atoll each year. Marie-Hélène was taken on the PSB staff half-time to handle the bibliographic and information needs of the project. The other half she was employed by my Pacific Vegetation Project, and soon taken over with that project by the USGS. This arrangement continued for 15 years, with mutual benefits to the two organizations.

One of the first activities started was a catalogue of atoll organisms. We soon found out that, though the flora and fauna were "impoverished", this meant that there were thousands of species, compared to millions. We also found out that the taxonomy and distribution of these thousands was in a primitive state, indeed. For many groups there were neither specialists nor monographs. And the literature was rife with misidentifications and identifications that could not be verified. We found, further, that for very few atolls were there even casual lists of even the most obvious, large and readily visible organisms. Here, indeed, was a long-term project, even to provide a basis for serious ecological studies.

Accumulating records of atoll organisms could, itself, have been a full-time task. We soon found that putting these records in order, organizing them taxonomically, determining their correct names, cross-indexing and properly placing synonyms, and even eliminating synonymous island names, was an enormous assignment. In the course of bibliographic work and reading geographic, ecologic, floristic and faunistic accounts, records of plants and animals, even in as limited an ecosystem as the part of coral islands above high tide level, accumulated enormously. And this was only one of the undertakings that we got involved in. We were actively bringing together and organizing the records for an annotated catalog of the Micronesian vascular flora, started back in 1946 as a project during the

Economic Survey of Micronesia. It later evolved into a full-scale descriptive flora, much of the material being used both in the Micronesian projects and in the coral atoll ecology work. After all a substantial number of the Micronesian islands are of coral limestone.

Each year, from 1950 through 1954, a major investigation of a selected atoll was carried out under PSB auspices, Arno atoll in the southern Marshalls (1950); Onotoa, in the Gilberts (1951); Raroia, in the Tuamotus (1952); Ifaluk, in the Carolines (1953); and Kapingamarangi in the Caroline Islands (1954), with a Polynesian people,were visited by interdisciplinary parties. Marie-Hélène supplied references, written information, and briefing to any member of these parties who wanted them. In return she handled a flow of information coming in from these same people, bringing their reports out in the ARB. She prepared reviews of a number of interesting atoll phenomena, e.g. the occurrence of pumice on atolls, and its significance; scorpions on atolls; abstracts and summary translations of accounts published in French and German; and a review of what was known of Aldabra Atoll in the western Indian Ocean (of which, more later).

During this same period, the USGS, taking advantage of ship transportation furnished by the U.S. Army Corps of Engineers mapping activities, carried out a major geologic, geographic, pedologic, and biologic survey of most of the northern Marshall atolls that had not been covered by the Crossroads Operation in 1946 and subsequent years. The data and specimens from this were grist for Marie-Hélène's mill, added to those from the PSB expeditions. Interesting ecological findings on the USGS expedition were the abundance and minor element role of floated pumice in atoll soils, and the mode of formation of bedded atoll phosphate rock through the combined agencies of bird guano, acid raw humus from Pisonia trees, rainfall, and coral sand. This phosphate was the basis of an exploitation industry on coral atolls in the second half of the 19th Century and the beginning of the 20th.

Editing and getting out the material from these investigations in the ARB became a major part of her activity. This added enormously to her knowledge, but left little time to get this knowledge digested and written down and published in integrated form.

After the five PSB expeditions, the ONR Geography Branch wanted the results brought together in a form that they could appraise and evaluate. Rather than the obvious course of having Marie-Hélène undertake this, they chose to have a professional human geographer do it. Though poorly prepared to handle the physical and biological aspects, he chose to treat these first, depending largely on the ARB reports and information supplied by Marie-Hélène. He took a trip through some of the Micronesian atolls to supplement his own field experience gained on one of the PSB expeditions, and to gain an overview. His lack of experience and training in these physical and biological aspects made the comprehensive volume (Wiens, 1962) that resulted disappointing in some respects, but on the whole it was a useful summary. He never proceeded to do the planned second volume on the human geography of atolls, which was his proper field.

The momentum of the program was slowed down by this interruption, and ONR support, though still forthcoming, was on a lesser scale and more episodic in nature.

Interspersed with this activity in the Pacific atolls were visits to several of the rather few Caribbean atolls. This started with a short visit of mine to Alacran Reef, Yucatan, leading to a visit by the two of us to Pedro Cays, south of Jamaica. About this time our colleague, David Stoddart, was initiating his career with investigations, over several years, of the coral cays and reefs off the Belize (British Honduras) coast. We were able to assist him with plant identifications and information, and with publication of his results in ARB. The occurrence of a devastating hurricane Hattie in 1961 gave him a chance to study "before and after" conditions, and to compare hurricane effects in the Caribbean with those observed by us, earlier, in the Pacific, especially on Jaluit Atoll, Marshall Islands, devastated in 1958. We also, in 1962, paid a visit to Dry Tortugas Keys, a Florida atoll, former site of

the Carnegie Institution coral reef laboratory of A. G. Mayor.

In 1958 Marie-Hélène visited Grand Cayman, a somewhat atoll-like high coral island making plant collections and gaining some further familiarity with the Caribbean strand and lowland flora.

The Smithsonian, in 1969-70 initiated Coordinated Investigations of Tropical Reef Ecosystems (CITRE) which aimed to be a major investigation in depth of a coral reef. Marie-Hélène was involved in the attempt to select a site for this investigation, and we both, with David Stoddart, participated in a two weeks "feasibility study" and preparation of a proposal. This was carried out by over 40 reef workers, on Glover's Reef, one of the three atolls off the Belize coast. This gave us a good chance to study in a preliminary way, the Caribbean equivalent of a Pacific atoll.

This CITRE proposal, after a tremendous investment of time and money, failed to get funded. Some of the Smithsonian participants then proposed, and got continued funding for, a much more modest project, investigations of Marine Shallow Water Ecosystems (IMSWE). This project is still continuing. Stoddart and I, with two colleagues, made a survey of the Belize Barrier Reef and Lagoon Cays, resulting in an account of the flora of the Belize Cays, of which Marie-Hélène was co-author. The IMSWE group are now conducting a detailed study of Twin Cays, mangrove cays in the Belize Barrier Reef Lagoon.

In 1955 Dr. H. J. Coolidge was informed of a plan to resettle on Aldabra Atoll, western Indian Ocean, a large number (said to be about 800) of Seychellois workers, displaced from their employment by the Egyptian take-over of the Suez Canal. Worrying about the effect of this on the only remaining population of the Indian Ocean giant tortoises, and also about the suitability of this atoll as a habitat for large numbers of people, he asked Marie-Hélène to compile what information was available on Aldabra. From her bibliographic studies she was able to do this, and to prepare a memorandum for him. From what was known, it seemed clear that lack of fresh-water and very limited arable soil, such a population could not possibly survive without continual food and water from outside. Dr. Coolidge was able to use this memo to help persuade the British authorities to abandon this plan. This made us very much aware of this otherwise obscure and little-known atoll.

A decade later we became aware of a joint plan of the Royal Air Force and the U.S. Air Force to establish a "staging post" on Aldabra. Although this plan was kept under security classification by both air forces, the aspects classified on the two sides of the Atlantic were not identical. With the cooperation of David Stoddart, first on Addu Atoll in the Maldives, then in England, we were able to pool enough information from press announcements and rumors to realize that if this plan were carried out, it would mean the destruction of the, to then, almost unaltered Aldabra ecosystm. The tortoises and a number of other endemic plants and animals would face extinction. We were able to enlist many strong people, and institutions such as the Royal Society, the Smithsonian, and the National Academy of Sciences, to urge the governments to try to find another suitable location for the staging post. After an extensive publicity campaign and debate in Parliament, the British government finally announced that, due to the national financial situation, this plan and other British military activities in the Indian Ocean would be abandoned. At about this time, starting with a preliminary survey, by Stoddart, Wright, and Rhine under Royal Society auspices, of Diego Garcia Atoll and Aldabra, one of the most comprehensive studies of a single island ever undertaken was started by the Royal Society. A field station was built and is still functioning, under Royal Society administration through 1981, since then under the Seychelles Research Foundation. From being one of the lesser known islands, Aldabra has now become possibly the best known oceanic island.

Although Marie-Hélène was never able to visit Aldabra personally, she was one of the most knowledgeable persons about it and had the satisfaction of having played a key part in saving the atoll in its natural state.

In 1957 the occasion of the Eighth Pacific Science Congress gave Marie-Hélène a trip around the world and a chance to see her first coral island,on an unscheduled 30-hour stop on Bermuda, fascinating, but scarcely a typical atoll. On one of the field trips at the Congress, she made the acquaintance of Dr. Roger Revelle, then director of Scripps Institution of Oceanography, which led, the following year, to her participation in a multi-disciplinary expedition, under Scripps auspices, to Clipperton Island, the only coral atoll in the eastern Pacific Ocean. Taking full advantage of this opportunity, and with her superb grounding in all aspects of atoll studies, she collected a vast amount of information, and the material for a magnificent series of papers (1960, 1961a, 1961b, 1962a, 1962b, 1963) culminating in a monograph of the natural history of the island, for which she was awarded her Doctor of Philosophy degree by her alma mater, the University of Montpellier, France, in 1961. Clipperton being a French possession, these publications gave her a professional status in France as well as in the U.S. and recognition that was on a firmer basis than anything she had enjoyed earlier.

A short visit of a few days in 1963 to Wake Island, central Pacific, gave her a personal acquaintance with a relatively dry type of atoll, giving more of a feeling of reality to some of the information she had previously only second-hand.

We acquired news of the existence of extensive field-notes by M. G. LeBronnec, aging self-taught naturalist, and long-time guide and collector for the Pacific Entomological Survey in the Marquesas Archipelago. This aroused our interest in that remote archipelago, and the likelihood of the disappearance of these notes when M. LeBronnec would pass on suggested that, with her French origin and command of the language, Marie-Hélène might be able to rescue and get LeBronnec's personal interpretation of these notes. With the aid of a grant from the American Philosophical Society, she spent two months at Atuona, Hivaoa, Marquesas, home of M. LeBronnec. She was able, in spite of his failing memory, and suspicion of her motives by some of his family, to make annotated transcriptions of most of the LeBronnec notes and to borrow his plant collections for study. She was also able to make valuable new collections of the not too well-known flora of these islands. This got her started in work toward a flora of the Marquesas, and enroute she was able to visit several atolls, especially the enormous atoll of Rangiroa, in the Tuamotus. This was the beginning of her lasting interest in French Polynesia, especially its many atolls. A second visit to the Marquesas broadened this interest and led to visits to other atolls in this region.

An opportunity to make a rather detailed reconnaissance of Tetiaroa Atoll, Society Islands, with me, on behalf of its proprietor, Mr. Marlon Brando, served to mature her understanding of atoll floras and the ecological processes taking place on such atolls. These and several other visits to French Polynesia, led to descriptions and floristic treatments of a number of atolls in the French area of the South Pacific. In 1982 she had first-hand experience with hurricanes and their role in the vegetation and geography of atolls, when several successive such storms devastated some of the atolls she had visited, and one of which occurred while she was in Tahiti. She was able to fly to several Society Islands atolls immediately after this storm and to record some of the results.

One of her projects that originated with her work in eastern Polynesian atolls was a detailed study of a widespread but rare atoll species of the genus Sesbania (Leguminosae-Fabaceae). This was Sesbania coccinea L.f. a lovely-flowered small tree, which exhibits island to island variation from Henderson Island and the Marquesas clear across the Pacific to New Caledonia and the Loyalty Islands. She finished a definitive paper on this and related species, and was to take it to Paris for submission for publication on the day after she fell finally ill. It is now in press in Adansonia.

Her last two visits to the islands were in 1985, to Tahiti for the International Coral Reef Congress, with a short fourth visit to Tetiaroa to assess recovery from the hurricane damage. Two months later, a visit to the small high Society Island of Maupiti, resulting in a flora, published herewith.

Her untimely death, July 19, 1986, left many tasks unfinished, much information unrecorded, and a loss of an encyclopedic source of help and advice to others interested in coral islands, volcanic islands, and Pacific geography.

The project on coral island ecology, of which the foregoing is a sketchy outline, illustrates and leads to several observations on long-term scientific projects. One, perhaps a truism, is that they are never finished. The more one discovers the more avenues open out for further investigation. Two, they result in a continuous stream of facts and conclusions, which, if not written down and published, will eventually be lost. Three, that it is poor economy not to provide intelligent and competent help to save the time of professional investigators. A good secretary, or even a competent file-clerk with some scientific experience would have saved a great deal of Marie-Hélène's time and energy, and much of what was in her head would now be available. Much, even of what she wrote down is unrelated or out of context. We had, for the first years, a well organized filing and retrieval system for our coral island information, and for biogeographic information generally, but it became too much for two people to handle and keep in order. A competent assistant to devote full time and attention to this augmenting mass of information under our direction would have paid off many times over, but we only had such a person for a short period. Finally, if there had been a reasonably assured source of support for our island work, a great deal of time spent in writing grant applications and proposals, energy spent in worrying even about continued funding for printing costs of the Atoll Research Bulletin, would have been saved and used for the work in hand. There is much to be said for assured continuing support, as may be seen in many European institutes, and in projects supported by our major foundations in the U.S., viz. Carnegie Institution, Rockefeller Foundation, etc. as compared even to successful "hand-to-mouth" enterprises such as even our major institutions and universities seem to favor, or perhaps are inevitable in a tradition of fiscal year budgeting and funding.

Marie-Hélène's list of publications and the list of papers published in the ARB speak for themselves as to our success, but given more continuity, especially in the area of technical and clerical help, this tangible success could have been more impressive.

We probably spread ourselves too thin, but the rewards of breadth of experience and the resulting understanding are not negligible. It is only a pity that so much has to die with us.

[For some small indication of the products of the kind of understanding referred to, see the article on "A Qualitative Description of the Coral Atoll Ecosystem", and the symposia "Climate, Vegetation, and Rational Land-Utilization in the Humid Tropics" and "Man's Place in the Island Ecosystem." (Proceedings of the Ninth and Tenth Pacific Science Congresses.)]

[If there seems to be rather much mention of my own part in this saga, it is because we worked closely together throughout these 36 years, and it is really impossible to sort out our respective contributions. I think it is safe to say that without the participation of either one of us this long-term series of investigations, at least in anything like the form described above, would not have taken place. That is not to say that extensive and important studies of coral reefs and islands would not have been carried out. They obviously would have. But the story would have been different. I am glad to have been able, here, to place on record my acknowledgement of Marie-Hélène Sachet's contributions to knowledge of coral islands. Her work on high islands and other enterprises, certainly very substantial, is another story.]

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TRIBUTES TO MARIE-HELENE

When I sent the notice of the passing away of Marie-Hélène Sachet, we had not thought of a memorial issue of ARB, so I did not solicit impressions, especially not with any idea of publishing anything, nor did I anticipate such a response. However, many dozens of her friends did respond, most, of course, in a very personal manner. In some of the responses were paragraphs that, selected and taken together, give a very appreciative picture of her personality, and that seem worthy of preservation. Others equally sincere and laudatory were on such a personal level that it might not have seemed appropriate to include them. The following were selected not to be repetitious, and, taken together, well express our appreciation and sense of admiration and of loss. My selection was guided by what she would have liked and also by her deep sense of privacy. I hope these excerpts do not leave too much of importance unsaid. My own sense of loss cannot be adequately expressed, but may show through in what others have said.

F.R. Fosberg

Des yeux vifs, un esprit acéré, une mémoire fine, une silhouette un peu courteaude, mais surtout de la gentillesse et de l'amabilité qui ne se laissent pas compter, et beaucoup de courage pour arpenter les vallées et les montagnes, parcourir les plages coralliennes, voilà Marie-Hélène Sachet, botaniste française qui a travaillé pendant trente ans à la Smithsonian Institution de Washington, spécialiste des iles du Pacifique et qui vient de s'éteindre le 19 juillet 1986; avec elle, s'éteint une grande amie de la Polynésie.

R. Koenig

I remember fondly my first meeting with Marie-Hélène, at the Coral Reef meeting in Miami. Though I do not know that she remembered meeting me at that conference when I later got to know her better, Marie-Hélène had already won a very special place in my heart. She had made a point of coming to listen to my paper, my first at a large conference, and took it upon herself to let me know afterwards what she thought of the presentation. Then, as on so many occasions afterwards she was full of constructive criticism. It was doubtlessly not a very polished presentation, and Marie-Hélène was not guarded in her critique, but at the time it was a tremendous boost to me as a doctoral student to have someone pay such attention and give so generously of her advice.

Colin Woodroffe

I had not known Marie-Hélène for very long; I first met her on Rarotonga in 1983 when she castigated me, in her own inimitable style, for not bringing her some pineapples from Mangaia. It was not until last year, around the time of the Coral Reef Congress, that I came to know her better. Even though this period of acquaintance was brief, she was enormously kind to me. The few letters that I have from her attest to her interest in my welfare and in the direction of my scientific career. In the latter regard, I feel that it was a great honour to converse with such an authority on the islands of the Pacific Ocean.

Tom Spencer

Anne and I were very sorry to learn that Marie-Hélène had passed away and I should have written to you much earlier. I always think of her at the UNESCO Symposium at Abidjan, but I must have met her before that. She had a very clear incisive mind and made a valuable contribution to vegetation studies. We shall all miss her.

P. W. Richards

During my visits to Washington to work on tropical plants you were both very helpful to me. There is no question that Marie-Hélène left her mark on Pacific botany.

Chris Davidson

I was deeply saddened to learn that Marie-Hélène had passed away. I honestly believed she was indestructible.

I know that I will miss her, even though I did see her so infrequently. She will be missed and her contribution to botany of all these remote islands as well.

Of course, you know how much I owe her. I learned from her how to be a professional and have always held her up as an example in my career.

Elizabeth S. Udui

I am so sad to learn your news of Marie-Hélène.

I was especially impressed when we last met, in Tahiti, with her fearlessness. In particular I remember an evening discussion with her there when she freely admitted to "feeling" the importance of nature, not just measuring it ... Oh, how sorry I am there are so few biologists like her, I lament her passing.

Katy Muzik

I see her now, so upright, so probing, and with such kindly humor, working along with you in all your manifold investigations. I deeply sympathize with you on this tragedy.

Helga & John Corner

Sri Lankan colleagues, especially the Collaborators of the Flora of Ceylon Project, are deeply saddened by the loss of this admirable scientific colleague and good helpful friend, Marie-Hélène Sachet.

Magdon Jayasuriya

I was always certain of a warm welcome and helpful advice whenever I have been in Washington.

Her contribution to coral reef science will of course keep her name alive for many who never had the privilege of knowing her.

David Griffin

I am writing to express my sympathy, and also the sense of loss I know reef scientists will feel on hearing the news of her untimely death. She will be much missed by her friends and colleagues, but her contribution to floristic knowledge of the Pacific Islands will always be remembered.

Barbara E. Brown

It must be a great blow to you that Dr. Sachet has died. Your names have been linked together in so many useful papers that will keep her memory alive to the workers interested in the Pacific flora. I offer you the sincere condolences of our staff.

C. Kalkman

She has done so much and still had so much to contribute.

Brenda Bishop

Your card-announcement and brief note that Marie-Hélène is no longer with you hit like a ton of bricks. I was totally unaware that she had been ill, and I am unhappy that I never thus gave her any expression of concern, understanding, commiseration and sympathy. The combination of you two was one of the most fertile and productive in science that I have ever known.

Frank E. Egler

The letter that contained the information about your dear lady having passed away was either misplaced or never got to me. I was saddened to hear from you that she left us but then as I walk along the beach and look at the shells in various stages of decay, and witness to all things changing and returning to their original components, I realize without alarm that this will happen to me as well. It's a part of the incomprehensible cycles and there is nothing to fear in anticipation of that change. I'm reminded so often here on the island that everything is in a constant fluid state and nothing remains the same from day to day and every new day brings in new difference. Sadness and a sense of loss wears away and changes too. If we can just learn to let go and not try to desperately hang on to a nonexistant changeless world, then it makes it a lot easier.

Marlon Brando

RECENT ACTIVITIES OF THE MICRONESIAN RESEARCH CENTER (MARC)

By

Hiro Kurashina, D. Ballendorf, K. Carriveau, M. Driver, B. Karolle, T. McGrath and A. Williams

Dr. Marie-Hélène Sachet was a long-time friend of MARC and the University of Guam who contributed regularly to the MARC Collections and our scientific journal MICRONESICA. Her scholarly works enhanced MARC's leadership capability to serve scientists who conduct research in the Pacific. She is sorely missed by all of us at MARC. As a tribute to her and at the request of Dr. F. R. Fosberg, we are contributing the following account of MARC's current role in facilitating scholarship in the western Pacific.

Since its inception, the Micronesian Area Research Center (MARC) has had a threefold mission: to develop a collection of Micronesian and Pacific area materials, research Guam and Micronesia from direct fieldwork and documentation within and outside the Collections, and communicate the results of this research through publications, teaching, and public lectures. In addition, MARC has taken steps to strengthen its community service within the purview of its expertise. The past year has seen the fulfillment of this mission in a way consistant with MARC's tradition and the promise for further development.

Even before MARC was formally organized in September 1967, work on its Spanish Documents Collection (SDC) had begun. MARC's first director, the historian Paul Carano, was anxious to bring to Guam copies of primary source documents so that the people of the Marianas could have readily available informational sources that had only been available in archives in faraway places. During the first ten years of MARC's existence, four Spanish language and history experts searched for, acquired, organized, transcribed, and translated materials for the Spanish Documents Collection. The members of this team of experts were Marjorie Driver (still with SDC at MARC), Sister Felicia Plaza, Professors Teresa del Valle and Dale Miyagi. Maria Teresa Arias, a journalist and historical researcher, has served as a MARC Research Associate in Madrid since 1980 and has located additional materials for the Collection. Several publications have resulted from the historical research and translations work in the SDC, among which have been the account of Fray Juan Pobre de Zamora in 1602 and Spanish governors Villalobos, Olive, de la Corte, and Ibanez y Garcia. Spanish documents pertaining to this region continue to enhance MARC's reputation as a valuable resource network both on and off island. In addition of Spanish translations, translations from the French, German, and Japanese have also been completed by University of Guam faculty and research associates. Their efforts have resulted in the publication of works by Augustus Marche, Karl Semper, George Fritz, and several Japanese authors.

The Pacific Collections in 1985-86 subscribed to 62 serial titles. Not including serials and continuations, 221 items were cataloged and added to the Collections. Approximately 2,500 items are awaiting cataloging presently. From the 1985-86 acquisitions budget for the Pacific Collections program, much of the funds were spent in acquiring materials on backlog. In January 1986, MARC Pacific Collections assumed responsibility for continuing the Micronesian Area Tropical Agriculture Database owing to the expiration of the USDA grant for that program. During the Fall and Spring

semesters, the Collections were open to the public an average of 39 and 49 hours per week respectively.

A principal purpose of the Micronesian Area Research Center is to serve as a research and teaching resource in the region of Micronesia. Among the Center's programs aimed at attaining this purpose, is the geographical research and teaching component which strives to provide opportunities and facilities for the acquisition, organization, dissemination, and exchange of information concerning Micronesia. Some of the specific programs of the Geography Unit are to: direct baseline research on the physical, cultural, and spatial aspects of the region; one such ongoing program has been the GEO MAP Project which identifies and classifies the toponymics of the individual islands in Micronesia. This project has integrated linkages within the University by utilizing the facilities of the Computer Center (Mainframe SQL System) and the College Work/Study Program (training and employing UOG students). Another program conducts areal research by investigating spatial relationships (man/environment activities) and complex interrelationships between temporal process and spatial interaction in Micronesia; and provides published results of these analyses. A relatively long term program has been to develop and produce for publication an atlas and gazetteer of Micronesia by emphasizing synthesis and cartographic methodolcgies. In addition to these programs within the Geography Unit, will be the responsibility of providing hypotheses on resource utilization and development (and other spatial topics) in the region, and the development and communication of heuristic devices for the research grant proposals. Furthermore, this unit will assist others in the Center by providing academic support for various programs and individual academicians.

There has been a constant interest in the prehistory, colonial history and modern history of the Marianas, the Carolines and the Marshall Islands. Archaeological research and applied research have both added greatly to MARC's wealth of informative data. Archaeology, by definition, is the study of the life and culture of ancient peoples. Archaeology of the Pacific is mainly concerned with the study of ancient Micronesian, Polynesian and Melanesian cultures. Examination of ancient Pacific Island cultures by means of archival work and field research has become one of the most active social science research endevors at MARC over the past several years. MARC now supports primary research mainly concerning the origins of human settlement in the Western Pacific; applied research in connection with historic preservation programs; and teaching archaeological methods to students enrolled at the University of Guam. For ever growing tourism-related construction activities, MARC also provides professional consulting services for effective cultural resource management.

Theoretical orientations of archaeological research include the dating of early Chamorro settlement sites on Guam by means of systematic data retrieval in the field and radiocarbon age determination. Elucidation of prehistoric adaptive strategies to volcanic high islands is another main research objective. Other research hypotheses are formulated with respect to the continuity and change in the material culture of the ancient Chamorro people. For these important research objectives, MARC has undertaken research projects at Tarague Beach, Tumon Bay, Asan, Merizo, Agat, Orote, Northwest Field, Naval Communications Station at Finegayan, and other localities on Guam and elsewhere in the Southern Mariana Islands.

The funding for such research has come from a number of organizations, including the National Geographic Society, the Gannett Foundation, the Guam Historic Preservation Office, the CNMI Historic Preservation Office, the U.S. Army Corps of Engineers, and the U.S. Navy, to name but only a few. For some of these research endevors, MARC has worked cooperatively with other regional research institutions such as the Bishop Museum in Hawaii and the University of Tokyo Museum in Japan. For the past two years, the Center for Field Research in Massachusetts has provided funding for the archaeological and anthropological research pertaining to the Cook Islands Marae found on the islands of Aitutaki, Atiu and Rarotonga. For this particular research program, the South Pacific Commission in Noumea, New Caldonia provided a grant-in-aid in 1986.

Applied research in response to contracts from the Army Corps of Engineers and the Pacific Division of the Navy keeps the research staff in contact with both the changing present day situation and the historical sources which formed it. Continued efforts to probe the Spanish Documents Collection have brought to light data on the period before intense colonization and research into the Spanish governors has created an excellent picture of the administration in the Marianas during the Spanish occupation. Documentation of the American Naval Period on Guam (1898-1950) from Navy and Marine Corps sources provides raw data on the present century. There has been a parallel interest in the German and Japanese administrations in Micronesia as well. Research is on-going into the local view point of the Japanese colonial achievement in the region as there seems to be continual praise for the improvement in the educational system and the standard of living as a result of the period of Japanese administration. Efforts have been especially aimed at gaining a better understanding of the Japanese period and several research grants have been obtained from both government and private sources for this endeavor. A collection of oral history materials relating to the WWII experience on Guam and other islands where battles took place, is constantly being made. The oral histories are gathered by taping interviews of eye-witnesses, and then transcribing the testimonies to typescript for use by scholars and researchers, as well as university students. This collection is small, but growing constantly.

Research has continued in specialized aspects of Micronesia such as the history of the missions, the impact of the whalers in Guam and the Marianas, the social and political developments in the TTPI during the American Period, the emergence of new nations and states, the growing interest of the Soviet Union in Micronesia, the adjustment of students to college life both on Guam and elsewhere, and computer-assisted reconstructions of Chamorro family geneologies.

The center has prepared bibliographies on Diego Luis de Sanvitores dealing with the first few years of the Spanish Colonial Administration, water resources on Guam, and Energy Literature for Guam, the Trust Territory, and American Samoa. Translations from original sources have been printed from the German and Japanese administrations in the Republic of Belau, and from the Spanish and French for Guam and the Marianas. Works also published include an archaeological survey of Guam, the site formation and cultural sequence at Tarague, an archaeological investigation at Merizo in the boat harbor area, social and cultural change in the community of Umatac, and the Spanish forts of Guam. The Working Papers contain a variety of information on the region. A newsletter is also produced containing news of events and research projects.

The members of the MARC faculty offer a variety of courses in the College of Arts and Sciences within the departments of history, anthropology, geography,and philosophy. They offer general introductory courses within their disciplines, area courses on the Pacific with emphasis on Micronesia, and some specialized courses. These range from cultural and economic geography to field methods in archaeology and archaeological theory, from Cultures of the World to the Philosophy of Religion. A number of faculty have given lectures in the MARC Seminar Series and in the College of Arts and Sciences Research Conference on the campus. Some have accepted invitations to speak before groups on the island and have given papers at conferences in North America and the Pacific which later appeared in journals. One of the professors earned a Fulbright fellowship and lectured at one of the Australian universities. He later gave lectures in Melanesia and Polynesia before returning home. During the last academic year, MARC faculty taught 11 courses in the College of Arts and Sciences, served on 22 University committees, and continued their membership in 29 professional societies or associations. Some 33 papers were published in various journals or in other types of information dissemination media. Twenty-four public lectures were presented as part of the MARC Seminar Series. MARC faculty, staff members and associates conducted 19 externally funded projects, and 22 self supported projects. Of the 19 projects with funding from external sources, five of them were federally funded while six were funded by grants and contracts from local government agencies. Eight

projects were supported by grants and gifts from various private foundations. New projects generated $170,522.00 from external funding sources and contributed to the increase in research productivity of MARC faculty over the past twelve months. With continued support and enthusiasm, these high standards for achievement will continue and increase in the years to come.

In closing, the faculty and staff of the Micronesian Area Research Center wish to express the sincerest condolences to the family and close colleagues of Dr. Marie-Hélène Sachet. She is sorely missed by us all.

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1. Basic information papers, by various authors. 1-25, Sept. 10, 1951.

2. Symposium on coral atoll research, by various authors. 1-14, Sept. 10, 1951.

3. Vertebrate ecology of Arno Atoll, Marshall Islands, by J. T. Marshall, Jr. 1-38, Oct. 15, 1951.

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Geochemistry and mineralogy of carbonate rock samples from Aldabra Atoll, Indian Ocean, by Stephen T. Trudgill, p.11.

History of goats in thc Aldabra Archipelago, by D. R. Stoddart, p.23.

Abbott's booby on Assumption, by D. R. Stoddart, p.27.

Penetration of host plant tissues by the stylets of the coccid Icerya seychellarum (Coccoidea: Margaroidea) on Aldabra Atoll, by S. Blackmore, p. 33.

Meteorological data from Ulul Island, Namonuito Atoll, by John Byron Thomas and Mary Durand Thomas, p. 39.

Marine benthic algae of Kayangel Atoll, Palau, by Roy T. Tsuda, p. 43.

Qualitative assessment of asteroids, echinoids and holothurians in Yap Lagoon, by Deborah A. Grosenbaugh, p. 49.

Acanthaster in the cultures of high islands, by Charles Birkeland, p. 55.

Acanthaster as a recurring phenomenon in Samoan history by John M. Flanigan and Austin E. Lamberts, p. 59.

Distribution and abundance of the Crown-of-Thorns Starfish Acanthaster planci) around Tongatapu Island, Tonga, by M. P. Francis, p. 63.

Rats as avian predators: discussion, by W. R. P. Bourne, p. 69.

Layard's bird hunting visit to Tromelin or Sandy Island in December 1856, by R. K. Brooke, p. 73.

A submersible, rechargeable, electric drill, by W. H. Easton, p. 83.

Artificial reefs in Discovery Bay, Jamaica, by Michael J. Risk, p. 91.

Distribution of the decapods Brachyura and Anomura (excluding Paguridea) of the Cryptofauna in the reefs near Tulear, by Mireille Peyrot-Clausade, p.101.

256. Cays of the Belize Reef and Lagoon, by D.R. Stoddart, F.R. Fosberg, and D.L. Spellman, 1-76, April 1982.

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292. Short original articles. by Various Authors, May 1985.

Non-selective fishing methods of Futuna (Horn Archipelago, West Polynesia), by Rene Galzin, p. 1.

Croissance et production de Chama iostoma dans le lagon de Takapoto, Tuamotu, Polynesie Francaise, by Georges Richard, p. 11.

First records of Wood Sandpipers, Ruff, and Eurasian Tree Sparrow from the Marshall Islands, by Manfred Temme, p. 23.

Classification of emergent reef surfaces, by F.R. Fosberg, p. 29.

Botanical visits to Krakatau in 1958 and 1963, by F.R. Fosberg, p. 39.

Clecklist of the herpetofauna of the Mascarene Islands, by D.D. Tirvengadum and R. Bour, p. 49.

Marine and terresterial flora and fauna notes on Sombrero Island in the Caribbean, by Nancy B. Ogden, William B. Gladfelter, John C. Ogden and Elizabeth H. Gladfelter, p. 61.

Vegetation and flora of the Lowendal Islands, Western Australia, by Ralf Buckley, p. 75.

Notes on a brief visit to Seringapatam Atoll, North West shelf, Australia, by B.R. Wilson, p. 83.

Sea snake collected at Chesterfield Reefs, Coral Sea, by Sherman A. Minton and William W. Dunson, p. 101.

The underwater morphology of Palmerston and Suwarrow Atolls, by J. Irvin, p. 109.

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FLORA OF MAUPITI, SOCIETY ISLANDS

BY

F. RAYMOND FOSBERG AND MARIE-HELENE SACHET

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FLORA OF MAUPITI, SOCIETY ISLANDS

By

F. Raymond Fosberg* and Marie-Hélène Sachet

Maupiti is the westernmost of the high islands of the Society Archipelago, in the south-central pacific (lat. 16° 27´s, long. 152° 15´w). Until the investigation reported here, Maupiti was the least well-known, botanically, of the high Society Islands except tiny Maiao. The only previous botanical visit of any consequence was by the late Dr. Jean Raynal, in 1973. A list of his collections was published by Dr. Marie-Hélène Sachet and Dr. Yves Lemaitre (1983). He found a number of species, particularly in moist habitats at higher elevations, that were not found in 1985. Many other species, especially exotics, were not found by him but were collected or seen in 1985.

This report includes an introductory section on the geography and vegetation, and a main portion listing the species of vascular plants known to occur, or to have occurred, on the island, with detailed descriptions of those of which time permitted a careful study, and brief descriptions of the remaining native species. Those suspected to have been brought by Polynesians in pre-European time are also described and discussed in some detail. Exotic species are either very briefly described or, especially in cases of very familiar weeds and ornamentals, merely listed with remarks on their occurrences and citations of specimens. Collections by Raynal are cited, as are those made on the 1985 expedition, with symbols indicating the herbaria where they are deposited. The Raynal specimens are in the herbarium of the Laboratoire de Phanerogamie Museum d'Histoire Naturelle, Paris (P).

Our visit was made under the auspices of and arranged by the non-profit organization, Have Mule Will Travel. The botanists were Dr. Marie-Hélène Sachet and F. Raymond Fosberg, assisted by a group of volunteers, listed below, and with the excellent cooperation of archaeologists, Eric Komori and Robert Harmon, who were concurrently engaged in an archaeological reconnaissance of the island. The volunteers, whose financial assistance made the investigation possible, were Jeanette T. Gillette, Sandra C. Hoppe, Catherine A. Jordan, Georgeann T. Kirk, Suzanne Kish, David W. Miles, Joe Morris, Mary K. Mount, Joy A. Townsend, and Randy L. Villa. These volunteers helped both the botanists and the archaeologists with the field and clerical work and were also good company.

Mrs. Edna Terai, owner and manager of the Hotel Auira on Aura Motu, and her mother, Madeleine, contributed far beyond the call of duty, to provide for the comfort and well-being of the party, and to make the investigations successful. They have our sincere thanks.

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Vegetation of Maupiti

Maupiti is exceptional among the Society Islands in having no trace of original natural vegetation left. Its two highest peaks are only 380 and 372 m, scarcely enough to induce much orographic rainfall. The land area of the volcanic remnant is only 3–3.5 sq. km. The coastal strip is from very narrow to, in places, completely lacking, the slopes ending at the lagoon shore. The motus (flat coral islets), however, are unusually extensive for the size of the island, 1.5 or more sq. km.

The most conspicuous landscape features are the high north/south ridge formed of erosion remnants of hard rock, lined with great vertical cliffs, and a number of similar but smaller rock remnants radially arranged around the periphery of the convex northern side of the island. These rocks are bare gray to black, vertical-sided, almost bare of vegetation. The central mountain mass is a high east/west ridge with several peaks on it ranging from 220 to 380 m, with sloping sides except for protruding rocky knobs that form the summits.

Before the arrival of the Polynesians, Maupiti was, in all probability, completely forested except for the cliffs and perhaps several of the rocky knobs. The nature of the original forests of the volcanic slopes is uncertain, as no descriptions exist, even of what the island was like when Europeans arrived. Judging by the prevalence of archaeological remains on the slopes, even the lower slopes were to some extent deforested by the aboriginal inhabitants, though doubtless much original forest remained. About all that can be said of this is that it was of a broad-leaf evergreen type, probably for the most part similar to the slope forests of the lowest 500 to 1000 meters on the other volcanic Society Islands. Almost all of this has now been altered beyond recognition, replaced by exotic and a very few persistent native tree species. The alteration on Maupiti has perhaps been more extreme than on the larger high islands.

The present condition, resulting from hundreds of years of severe human exploitation and abuse, may be described, superficially, in rather simple terms, with the understanding that most of the plant species making up the present vegetation are exotics, not present in the original vegetation.

The narrow coastal strip, largely occupied by home-sites and the village, supports a mixed, largely "tree garden" type of vegetation. The trees that dominate the landscape are the breadfruit (Artocarpus altilis), mango (Mangifera indica), purau (Hibiscus tiliaceus), the coconut (Cocos nucifera), mape (Inocarpus fagifer), Java plum (Eugenia cuminii), tamanu (Calophyllum inophyllum), with an under layer of banana (Musa sapientum) and cassava (Manihot esculenta), and an abundant growth of weeds, especially Triumfetta rhomboidea, Elephantopus mollis, Sida rhombifolia, Bidens pilosa and Emilia fosbergii, along with a thick ground cover mat of Vigna marina.

A profusion of ornamentals, mostly the abundant pan-tropical ones, surround the dwellings and other buildings.

On and just back of the beach ridges and rocky shores is a fringe of Hibiscus tiliaceus, Thespesia populnea, Hernandia sonora, Guettarda speciosa, Cordia subcordata, Tournefortia argentea, with shrubs of Scaevola sericea and Suriana maritima, and a dense ground cover of Vigna marina, a vine which also climbs into the trees. On low flats that are occasionally flooded with sea-water, are scattered Hibiscus tiliaceus and dense stands of salt-grass, Paspalum distichum.

Above the coastal flats the lowest slopes are covered by a dense forest of Mangifera and Inocarpus, with some Hibiscus tiliaceus, patches of Coffea arabica, Cordyline fruticosa and scattered coconuts. Above the lowest slopes, Cocos nucifera becomes much more common, giving character to the landscape.

The ravines, up to their heads, are occupied by dense stands of Mangifera with Inocarpus fagifer also common and large, some Hibiscus and occasional tall Erythrina variegata and shrubs of guava

(Psidium guajava). Ferns --Nephrolepis, Polypodium, Davallia and Thelypteris, make much of the ground layer on the slopes and in ravines, along with other abundant weedy herbs. Heavy vines and lianas, such as Canavalia cathartica, Abrus precatorius, Merremia peltata and Derris malabarica form tangles in much of the ravine and slope vegetation.

On the middle and upper slopes and steep ridges the prevailing vegetation type is a tangled scrub or scrub forest of primarily Hibiscus tiliaceus, with locally much Psidium guajava. This, with a ground layer of weeds and Polypodium scolopendria, is the most widespread and prevalent vegetation type on the volcanic mass of the island. It is most difficult and tiring to traverse, even with the aid of a machete. In places in this are small clumps and patches of sword grass, Miscanthus floridulus, possibly relicts of former large stands.

On some more level ridges and saddles is a scrub forest of several broad-leaf shrub and small tree species, Ficus prolixa, Glochidion sp., Colubrina asiatica, Plumbago zeylanica, with the inevitable Hibiscus tiliaceus. On the sides of some of these ridges, Gleichenia linearis forms patches, but is much less common than in the higher, wetter islands.

On high south and southwest slopes and ridges are areas of Miscanthus floridulus grassland, possibly traces of rain-shadow effect. The small amount of this vegetation is one of the curious aspects of Maupiti vegetation. Considering the prevalence of burning of vegetation on this island large areas of Miscanthus savanna would be expected, but this vegetation type is not at all extensive.

Judging by the collections made by Jean Raynal, in June 1973, one would have expected a considerably richer and more hygrophilous vegetation at high elevations than was encountered in 1985. A number of species, including some epiphytes, found by Raynal, could not be located on the 1985 survey. The condition of the vegetation generally, in 1985, suggested that there had been an unusually dry season or seasons previously. This might have resulted in a poor representation of some mesophytic species. However, the scarcity or complete or almost complete absence of a good number of these, may be the result of repeated uncontrolled burning which denuded the upper slopes. Evidences of extreme erosion on some of the ridges and steep slopes strengthens this suggestion, and burning may be responsible for the relative poverty of both flora and vegetation now observable on this island.

The extensive motus have almost no physiographic relief. The principal variations are low beach ridges (on the seaward side of Motu Auira to as much as 6–8 m), and wet marshy depressions, in places to below water-table. These may be remains of old taro-pits, now largely colonized by dense pure stands of saw-grass (Cladium jamaicense) and very locally by Cyperus sp. and even more locally by stands of Typha domingensis.

The original vegetation of the motus was cleared and replaced by coconut plantation. Burning of the herb and shrub regrowth in the plantations is, and probably has been, prevalent, and has encouraged the abundance of a number of species that may withstand at least moderate fire. Such species are Euphorbia aff. atoto, and Timonius polygamus, both slender shrubs with rather thick root crowns from which sprouts issue after burning. Practically all coconut trees seen showed charring around their bases, some being seriously burned. On the lagoon sides the plantation comes to the top of the beach ridge, which is here very low, in places scarcely evident. Such trees as Guettarda, Cordia, and Hernandia are commonly found along the lagoon beaches and beach ridges, more sparingly inland. Suriana maritima and Scaevola sericea are common shrubs at the top of the lagoon beach, in places forming conspicuous fringes.

On the ocean side more diverse woody vegetation persists on the beach ridges where it has not been recently cleared for watermelon cultivation. Here the beach ridges are higher and the beaches broader. Suriana and Guettarda are principal components, with coconuts rather sparse. Lepturus repens is the principal herb component, here, as elsewhere. Euphorbia and Timonius, as well as Suriana, form a notable shrub layer. Cassytha, a leafless orange to green string-like twining parasite,

tangles everything together in places.

The coconut plantation is much more open, or even sparse, on these motus, than is usual on other similar islands in the Societies and elsewhere. The frequency of fallen coconut trunks and of seedling regeneration suggests that this sparseness may be the result of a series of hurricanes several years ago. Some areas are quite open and the vegetation is dominated by Euphorbia, with, in places, Timonius, and often an abundance of Lepturus. In more shaded places the ferns Nephrolepis, Polypodium, and more locally, Davallia, form a large part of the ground layer. Cassytha is very frequent, more so in more open situations. Tacca is locally common, especially toward the lagoon side. On the west and northwest side of Motu Auira, back of the broad beach ridge, there is a broad flat zone quite open and free of coconuts, even of seedlings. Pandanus and Guettarda are scattered sparsely over this. The main cover is a mixture of Euphorbia, Timonius and Suriana, the latter abundant especially toward and on the beach ridge, with Lepturus locally abundant between the shrubs. Cassytha is very common, and Scaevola sericea var. tuamotensis appears abundantly near and on the beach ridge.

Here and there, on the motus, are stands of woody plants - shrubs and trees, not commonly abundant on low coral islands. Such are dense Leucaena leucocephala on Motu Tuanai and patches of forest of Eugenia cuminii on Motu Auira. Ferns are unusually abundant, mostly Nephrolepis rufescens, on the south end of Motu Tuanai. Near Perue on Motu Tuanai, west end, is a shallow desiccating lake or pond called Roto (?), surrounded by dense stands of Pemphis acidula, not seen elsewhere on Maupiti. Near the desiccated part of the pond the Pemphis seems in very poor condition, almost leafless, while on slightly higher ground, back of this, it is flourishing and leafy.

Copra-making does not seem to have been very active recently, judging by the abundance of sprouting nuts generally and the number of ripe, un-cut nuts on the ground almost everywhere in the plantations.

In recent years there has been a surge of watermelon (Citrullus lanatus) cultivation on the motus. Areas of coconuts are cleared. Weeds which then grow in great abundance, are killed by application of herbicides, then burned. Quantities of volcanic soil are brought from the main island, placed in pits where watermelons are then planted. Quantities of phosphate are applied, and water, dipped or pumped from the fresh-water lens a meter or two below ground surface, is poured or sprayed on the plants. Excellent watermelons are produced in some quantities and shipped to Tahiti. The consequences of removal of large amounts of soil from the coastal strip and lower slopes of the island are not fully understood but agriculture on the volcanic slopes can scarcely benefit. The practice of burning results in an even greater lack of organic matter than usual in coral soils.

The abundance of Vigna marina on both the coastal strip and lagoonward parts of the motus may contribute substantially to the nitrogen content of the soil, as may Nostoc and other myxophytes in and on the surface of the coral sand and rock.

The Maupiti Flora

Floristically the island is, at present, impoverished, though this may not always have been the case. The proportion of exotic species is high, and their abundance very great. That they have all replaced indigenous plants is a truism, but suggestive that the native flora must once have greatly exceeded the 237 native species now on record.

The flora of the volcanic parts of the island has probably suffered the greatest loss of both species and numbers of individuals of indigenous kinds. Jean Raynal, who collected here in 1973 is said to have devoted most of his effort to the higher areas. He got a number of species not found in 1985 as well as several more that are now very scarce. Those now missing or scarce are the most mesophytic, reflecting the present denuded condition of the ridges and summits. The slopes and ravines, which once must have had a fairly mesophytic flora, at least on the windward side, are now almost entirely occupied by exotics, both woody and herbaceous. The coastal strip is, except for the strand, covered

by exotic trees and shrubs, mostly either economic or ornamental.

The motus, though they have been completely converted to coconut plantations, have probably retained a greater proportion of their indigenous flora than the high island, though their original total flora may probably have been much smaller. Most of the atoll species are pioneers or salt-tolerant plants and hence, better able to survive clearing and exposure. Even so, a few species that might be expected in large motus such as these were not seen. Pisonia grandis, for example, seems completely lacking. Pemphis acidula is very local and in an unusual habitat, on sand flats and edges of a brackish pond. Neither Hedyotis romanzoffiensis nor Digitaria stenotaphrodes were found.

PTERIDOPHYTA n.v. ferns and fern allies

PSILOTACEAE

Psilotum Sw.

A pantropical genus with two or more, probably four, species, one in Maupiti. Often considered the most primitive living vascular plant.

Psilotum nudum (L.) Beauv.

Tufted, usually erect, leafless bright green plant, 1.5 – 3.0 dm tall, stems congested, from a usually very short rhizome, stems longitudinally angled, several times dichotomous, without evident nodes, leafless but with scattered small subulate appendages, these paired on ultimate branches bearing 2 large yellow globose sporangia subtended by each pair.

Pantropical species, very rare on wooded slopes on Maupiti, terrestrial, rarely epiphytic.

Fosberg 64897 (US)

SELAGINELLACEAE

Selaginella Beauv.

Herbs with scale-like leaves and spores of 2 sizes, the smaller ones distal in the fruiting spike.

A very large cosmopolitan genus with very diverse habit and adaptations, one species rare in Maupiti.

Selaginella societatis Moore ? n.v. remu tiare

Small delicate herb, branching in one plane, leaves very small, thin, green, scale-like, in 4 ranks, two of them larger and lying in same plane as branching; fruiting spikes terminal on branches, narrower than leafy branch.

Found once in Maupiti but not seen on 1985 survey.

Raynal 17831 (p. 1337)

GLEICHENIACEAE

Gleichenia Sm.

Dicranopteris Bernk.

Ferns with usually pseudo-dichotomously forked fronds, pectinate ultimate segments, and naked sori.

A pan-tropical genus, often divided into 4 genera, but by us these are regarded as sections of Gleichenia. Common on tropical mountains, a few lowland species. One species in Maupiti.

Gleichenia linearis (Burm. f.) C. B. Cl.

Buried elongate hard rhizomes bearing widely spaced fronds, these several to many times pseudo-dichotomously branched, a pair of reflexed pinnae at each forking and a coiled innovation or an elongate segment of rhachis in each forking, elongation indeterminate, producing complex tangles.
In Maupiti seen only very locally on high steep slopes.
Fosberg 64777 (US)

POLYPODIACEAE (sensu lato)

By many botanists divided into a number of smaller families.

Acrostichum L.

Fronds large, leathery, fertile ones with upper part of blade solidly covered by crowded sporangia.
A pantropical genus of several coarse aquatic or semi-aquatic species, one rare in Maupiti.

Acrostichum aureum L.

Rhizomes short, erect, crowded together, producing slender stolons; fronds erect, to 1.5 m tall, base clothed with stiff blackish ovate scales with erose brown margins, closely appressed to base of stipe, frond hard-coriaceous, broadly lanceolate in outline, simply pinnate, pinnae lanceolate, ascending, to 25×5–6 cm, acute, base obtuse, on a short stalk to 1.5 cm, lowest reduced to short point-like rudiments on sides of the stipe, these remote; fertile fronds like sterile, but upper few pairs of pinnae completely covered with sporangia, these pinnae after shedding spores drying and twisting while rest of frond continues green.
A pantropical fern found in both fresh and saline marshes, water seeps, and swamps, especially around edges of mangrove swamps. In Maupiti only small patches of a few sq. m, on N-W coast, in saline flat.
Fosberg 64915 (US)

Adiantum L.

A cosmopolitan genus of many species, with membranous flabellately veined leaflets arranged from simply pinnate to decompound, usually in one plane. One species rare in Maupiti.

Adiantum hispidulum Sw. n.v. amo'a hu'a

Small tufts of slender long-stipate pinnate fronds, pinnae thin, with sori concealed by turned under flaps of margin of pinna.
Collected once in Maupiti, not seen in 1985.
Raynal 17836 (p. 1337)

Asplenium L.

Rhizome usually very short, often erect, fronds entire to variously divided, blades tending to be firm; sori with linear indusia lying along veins.
A very large cosmopolitan genus, one species in Maupiti.

Asplenium nidus L. n.v. 'oaha bird's nest fern

Fronds entire, arranged in a large nest-like rosette that collects leaf litter, veins many, pinnately parallel, with elongate linear sori, covering part or most of blade.
An Indo-Pacific fern, either epiphytic or terrestrial, in Maupiti rare on shaded rocks at middle to high elevations.
Raynal 17856 (p. 1338), Fosberg 64900 (US); Morris 10 (US)

Davallia Sm.

A large tropical genus, fronds tending to be triangular, rhizome creeping, sori in marginal tubules. One species common in Maupiti.

Davallia solida Sw. n.v. titi

Rhizome thickish, covered with hair-like brown scales, creeping, fronds scattered, much divided.
Widespread and common in the Pacific islands; on Maupiti common in shaded places at all elevations, all plants examined were sterile.
Raynal 17839 (p. 1338), Fosberg 64828 (US), 64874 (US).

Doryopteris J. Sm.

Small ferns with short rhizome, few fronds, triangular blades that curl when dry, variously divided; sporangia borne under reflexed margin of segments.
Widely distributed small tropical genus. One species rare in Maupiti.

Doryopteris concolor (Langsd. & Fisch.) Kuhn

Small tufts of fronds with straight wiry stipes, triangular palmately divided blades, curled when dry.
A rather widely distributed Pacific species, rare in Maupiti, growing in rock crevices.
Morris 7 (US), Fosberg, sight record.

Humata Cav.

Usually epiphytic, with slender scaly creeping rhizomes, entire or usually dissected fronds, sori with transversely oblong or reniform conspicuous indusia.
A rather small genus in the Malayan-Pacific region, one species in Maupiti.

Humata pectinata (J. E. Sm.) Desv. sensu lato n.v. feti'i no te titi
Humata banksii Alston

Small fern with fronds scattered on rhizome, stipe about equalling the triangular pinnately lobed blade.
A widespread Polynesian and western Pacific species, several forms of which have been described as species. Epiphytic, found once on Maupiti but not seen on the present 1985 survey.
Raynal 17845 (p. 1338)

Nephrolepis Schott

Rhizome usually erect, bearing slender elongate stolons, crowded mostly erect fronds, normally simply pinnate with articulate pinnae, sori with round to cordate or reniform indusia, usually a row of white dots on the upper surface of pinna, marking the positions of the sori.
A pantropic genus with one species native in Maupiti, another one planted.

Nephrolepis biserrata (Sw.) Schott

Rhizome slender, erect, blackish, covered with hard, black convex glossy reticulate scales with cinnamon-colored tomentose margins, rhizome producing hard wiry dark brown stolons sparsely scaly with hard black-based scales; fronds ascending to arching-spreading, pinnate, lanceolate in outline, to 2 m long, pinnae lanceolate, tapering, to 10 or more cm long, a few somewhat reduced ones toward base, sessile, acroscopic side broader, more truncate, almost glabrous on both sides or, fertile pinnae

slightly scaly on costa beneath, rhachis somewhat, but not densely scaly, scales peltate longer than wide, pointed at ends, hyaline with dark point of attachment, irregularly ciliate, turning brown with age, margins of sterile pinnae subentire (?) to subcrenate, undulate; margins of fertile pinnae crenate, sori submarginal, slightly in from sinuses, indusia subpeltate to orbicular-reniform, openings pointing backward and somewhat inward.

A widely distributed pantropic species, probably planted, at least on Motu Auira.

Fosberg 64836 (US)

Nephrolepis rufescens (Schrader) Wawra n.v. amoa

Nephrolepis acuta var. subferruginea Hook.

Rhizome erect, covered by imbricate red-brown fimbriate scales, their apices blunt, an abundance of elongate cordlike axillary stolons 1.5–2 mm thick, covered by hyaline somewhat reddish broadly lanceolate scales with peltate bases; fronds pinnate, pinnae articulate, crowded tending to be erect or arching, rhachis dark brown, thickly covered with narrowly lanceolate to almost hair-like red-brown scales, these tending to be hyaline with dark brown bases on young fronds, some older fronds with rachis appearing gray-woolly above; outline of frond narrowly lanceolate, sterile ones broader, pinnae close together distally, becoming shorter and more remote toward base, linear lanceolate spreading almost in a single plane or slightly inflexed, apices blunt to acute, fertile ones narrower, more acute, both surfaces sparsely pale brown-scaly, more densely so on and near midrib, scales spreading, pinna-margins undulate or subcrenate, sori sub-marginal, indusia orbicular to narrowly reniform, cordate base directed downward and inward.

Fosberg 64779a (US); 64839 (US); 64847 (US) Raynal 17858 (p. 1338)

Polypodium L., sensu lato

We choose to maintain Polypodium L. in a rather broad sense, including Microsorium, Phymatodes, Phymatosorus, Phlebodium and other groups closely allied to Polypodium L. sensu stricto, but excluding Grammitis and its close relatives. In this sense Polypodium is a readily recognized and convenient group of ferns of world-wide occurence.

Rhizome usually creeping, sometimes very short and fronds crowded; fronds usually articulate to rhizome, simple, entire or much more usually pinnately lobed; sori without indusium, in rows or scattered, venation ordinarily anastomosing or reticulate.

Polypodium maximum (Brack.) Hook. n.v. metua pua'a 'ata ho'e

Fronds erect, to 0.8 m, from thick horizontal rhizome, rhachis very broadly winged, one or two pairs of lobes spreading at right-angles, venation reticulate sori on terminal lobe, small, scattered.

Rare on Maupiti, at higher elevations.

Raynal 17852 (p. 1338) Morris 9 (US)

Polypodium punctatum (L.) Sw. n.v. 'irio peho

Rhizome creeping, short, fronds crowded, entire, linear to linear lanceolate, acute or acutish, sori scattered, small.

Widespread in Old World tropics; found once on Maupiti, but not seen on 1985 survey.

Raynal 17851 (p. 1338)

Polypodium scolopendria Burm. f. n.v. metua pua'a

Rhizome stiff, creeping, 6–10 mm thick, hard-fleshy, strongly diagonally dark-banded by overlapping rows of ovate or ovate-lanceolate acuminate scales, these peltately attached closely and firmly appressed to surface of rhizome, body of scale strongly black-cellular-reticulate, areolae clear, roughly in rows and longer than wide; fronds scattered, erect, articulate to rhizome, an imbricate loose

band of smaller similar scales around articulation; bushy masses of intricately branching roots on lower side of rhizome; stipe round, shorter than blade, upper part black; blade thin-coriaceous, ovate in outline, lobed almost to midrib, up to 6 or more linear-lanceolate lobes alternate on a side, terminal one similar, longer, apices acutish to rounded, sinuses round; no sharp difference between fertile and sterile fronds, terminal, upper, or almost all lobes with one, rarely 2 rows of large orbicular orange sori with no indusia, sori showing through on upper surface as raised disks or rings, pale green on bright green frond surface.

Widespread Indo-Pacific species, commonest in lowlands and coastal habitats, but also common on mountain sides and ridges; in Maupiti common generally, on mountain slopes very erect and very large.

Raynal 17853 (p. 1338), Fosberg 64798 (US), 64981 (US)

Pyrrosia Mirb.
Cyclophorus Desv.

Epiphytic ferns with creeping rhizomes, scattered coriaceous, entire fronds with peltate-stellate scales; sori naked.

A widespread Old-World tropical genus, one species known from Maupiti.

Pyrrosia blepharolepis (C. Chr.) Ching — n.v. ripene
Cyclophorus blepharolepis C. Chr.

Rhizome slender, scaly with acuminate brown-tipped scales, scales of blade with black centers, white rays, lamina of blade sub-fleshy, coriaceous.

An epiphytic fern, found once on Maupiti but not seen on 1985 survey. Raynal 17855 (p. 1338)

Thelypteris Schmidel
Dryopteris Adans., pro parte, excl. type.

Ferns usually with once-pinnate fronds, but pinnae usually lobed, sori small, indusiate or rarely naked, indusia round to cordate or reniform but not truly peltate, venation free and forking or somewhat anastomosing.

A very large almost cosmopolitan genus, formerly united with Nephrodium (= Tectaria) or Dryopteris, now separate, and by some segregated into a multitude of small, ill-distinguished "genera"; one species in Maupiti.

Thelypteris forsteri Morton — n.v. amo'a 'ata ho'e
Dryopteris invisa (Forster) 0. Ktze. (non Thelypteris invisa (Sav.) Proctor).

Rhizome creeping, buried, fronds broadly lanceolate in outline, arching, pinnae only lobed 1/3 to costa, but appearing more deeply so, sori on similar fertile fronds, in one row reaching almost to midrib from each lobe.

A widely distributed Pacific fern, common on wooded slopes on Maupiti.

Raynal 17857 (p. 1338), Fosberg 64769 (US); Morris 16 (US), 17 (US).

SPERMATOPHYTA

Spermatophyta — n.v. seed plants

TYPHACEAE

Typha L.

Emergent aquatics with buried rhizomes, basal erect linear entire, firm leaves, erect hard cylindric flowering stems each bearing two spikes, lower one pistillate, upper staminate, on same rhachis, flowers densely crowded, fruits minute, shed as a cotton-like mass, spread by wind.

A few species, very difficult to distinguish.

Typha domingensis Pers

Tall reed-like stems to 3 m or more from an underground rhizome system, leaves linear, distichously arranged, basal, sheathing at base, 2–3 m long, about 12–13 mm wide, smooth margin, inflorescences with pistillate and staminate portions each about 30 cm long, separated by about 1 cm. staminate arcuately nodding.

Probably introduced in the Society Islands, known at least from Tahiti, Moorea and Raiatea on coastal flats; in Maupiti on Motu Auira in marshes near lagoon side.

Fosberg & Sachet 64981A (US)

PANDANACEAE

Pandanus L.

Trees, shrubs or rarely almost acaulescent, trunk supported by woody prop-roots, sparsely branching, branches thick, ringed by leaf-scars; leaves linear, stiff, hard, usually somewhat folded, usually spiny on margins and midrib; dioecious; flowers reduced to tufts of stamens or single or several united carpels; staminate inflorescences branched, bracteate; pistillate of single or multiple heads; fruit drupaceous.

A widespread Old-World tropical genus of many species, one in Maupiti.

Pandanus tectorius Park.

A very widespread species in Polynesia, Malayan Archipelago, Ryukyu Islands, and also in the Western Indian Ocean; common especially at low elevations and on motus in Maupiti.

Fosberg, sight record.

POACEAE (GRAMINIAE)

The grasses, one of the largest plant families, many genera.

Cenchrus L.

Grasses with spike-like panicles of spiny, burr-like involucrate spikelets.

Widespread in tropical and warm-temperate regions, two species known from Maupiti.

Cenchrus calyculatus Cav. n.v. sand-bur

Perennial, with small clumps of leafy stems, involucres not strongly spinose, with many bristle-like slender spines.

Widespread, but never common, in Polynesia; one clump found on a low ridge in open scrub on S W corner of Maupiti.

Fosberg 64763 (US, BISH, Papeete)

Cenchrus echinatus L. n.v. piripiri; sand-bur

Annual (or short-lived perennial) grass, several stems slightly decumbent from a branching base, lower sheaths purple, strongly compressed, sharply carinate, lower internodes short, lower nodes geniculate, culms ascending to erect upper part exserted, blades narrow, slightly folded, long tapering, held at an angle to sheath, base of blade long hirsute above, ligule a dense row of hairs; panicle spike-like (or raceme-like, bases of spikelets obconic, pedicel-like), 2–3 cm long, rhachis narrow, slightly marginal, undulate, spikelets not crowded, involucrate, involucral segments in 2 series, the outer

numerous, setose-spinose, the inner series with thickened indurate bases, coherent into a hard base, the free parts sharply spinose, the whole enclosing membranous bracts and the grain; the whole structure very readily disarticulating from the rhachis when mature.

A pantropical weed, carried around readily in animals' fur and peoples' clothing, very annoying; common in Maupiti.

Fosberg 64840 (US)

Centotheca (or Centosteca) Desv.

Broad-leafed grass with cross-veins between the parallel nerves, spicate panicles.

Centotheca lappacea (L.) Desv. n.v. 'ofe'ofe

Usually erect, scarcely caespitose, rather slender grass, with broad, wavy-undulate blades, many spike-like branches ascending from a short rhachis, later deflexed, spikelets deciduous and clinging to clothing when mature.

A very common Western Pacific and Polynesian grass; common on slopes especially shaded ones in Maupiti.

Raynal 17859 (p. 1338), Morris 4 (US); Fosberg 64800 (US); 64817 (US).

Coix L.

A rather coarse, broad-leafed grass, with spikelets monoecious, pistillate enclosed in a hard, smooth, nut-like involucre.

Coix lachryma-jobi L.

Indo-Pacific species, spontaneous or planted for use in seed-jewelry. One tiny colony of several plants seen in edge of village on Maupiti.

Fosberg, sight record.

Cynodon Rich.

Wiry stoloniferous or rhizomatus grasses with digitate clusters of spikes-like branches on erect culms.

Cynodon dactylon (L.) Pers.

Creeping, branching, mat-forming grass, internodes numerous, short; leaves small, broadly linear, glabrous except for a few conspicuous hairs inside summit of sheath; ligule very narrow, membranous, entire, fertile culms well-exsertes, 3–4 narrowly linear spikes widely divergent from summit of fertile culm; spikeelets closely appressed, second glume half or more as long as spiklet, rachis narrow slightly carinate, spiklets ovate, 1 floret.

Pantropical and warm-temperate weedy grass, used for lawns where more attractive grasses do not do well; in Maupiti common around dwellings and in trampled places, component, with other grasses, of lawns, doubtfully native.

Fosberg 64913 (US, BISH)

Digitaria Heist

Tufted usually slender grasses, often annual or in wet years perennial, spike-like racemes usually digitate or subdigitate, spikelets solitary or usually in pairs (or 3's), one pedicel longer, one-flowered, usually lanceolate or narrowly ovate, glumes tending to be reduced, lower one even absent, sterile lemma well-developed, with 3 or more strong nerves, fertile lemma strong, smooth, enclosing the palea and flower-parts.

Digitaria ciliaris (Presl) Miq. n.v. Crab Grass

Decumbent herb, stems spreading from a loose tuft, several lower internodes, then culms ascending, sheaths long, carinate but not strongly so, blades lanceolate, at an angle to sheaths, ligule hyaline, prominent; racemes 3–4, 2 lower ones subopposite, divergent, upper 1 or 2 notably above lower ones and opposite, or uppermost shortly stipitate; spikelets broadly lanceolate, 3 nerves visible dorsally, first glume present, triangular scale-like, very short, second glume lanceolate, hairy, 1/2–2/3 length of spikelet, sterile lemma about equalling spikelet.

Widespread tropical equivalent of temperate D. sanguinalis, found in weedy places.

Fosberg 64841 (US), 64834 (US).

Digitaria radicosa (Presb) Miq.
Digitaria timorensis

Slender grass with few digitate spike-like panicles; rhachis margin smooth or almost so, first glum tiny or lacking, second glume about half length of spikelet.

Occasional in open or semi-open grassy areas and roadsides.

Fosberg 64766 (US), 64879 (US).

Digitaria setigera Roth

Slender decumbent grass with digitate spike-like panicles, lanceolate spikelets, lower glume wanting or very minute, upper, less than half the length of spikelet.

A common Indo-Pacific species, found occasionally on Maupiti in open weedy places and along paths.

Fosberg 64758 (US), 64803 (US), 64920 (US, BISH, Papeete)

Echinochloa Beauv.

Annual or perennial grasses with racemosely arranged panicles of uniflorous spikelets. One species, probably introduced, in the Society Islands.

Echinochloa colonum (L.) Beauv.

Stems spreading, with several leaves, panicle of several short branches of crowded uniflorous spikelets, awnless.

A very widely distributed weed of ruderal habitats, occasional in lowlands on the main island of Maupiti.

Fosberg 64790 (US)

Eleusine Gaertn.

A small genus of weedy and economic grasses, very widespread; one weedy species in Maupiti.

Eleusine indica (L.) Gaertn.

Small slightly decumbent tufts, culms ascending with several digitately arranged spicate panicle branches; grain oblong, promanently rugose.

A cosmopolitan weedy grass with a very tenacius root system, common on Maupiti.

Raynal 17865 (p. 1338), Fosberg 64842 (US).

Eragrostis Host

A large genus, mostly of warm countries; one widespread weedy species in Maupiti.

Eragrostis amabilis (L.) W. & A. n.v. love-grass
Eragrostis tenella (L.) Beauv.

Slender depressed to erect grass, leaves linear-lanceolate, several mm wide, strongly pilose at summit of sheath and base, panicle fine, diffuse, branches wide spreading, spikelets very small, florets about 8, lemmas green to purplish.

Widespread tropical weed; in Maupiti common in disturbed places, especially around dwellings.

Fosberg 64912 (US)

Lepturus R. Br.

Tufted, but tufts often producing ascending branches or prostrate stolons, inflorescence a jointed cylindrical spike with spikelets appressed into grooves in the rhachis.

A few widely distributed coastal species, very variable, and several more restricted or even local endemic species, some of doubtful status. One wide-spread species very common on Maupiti.

Lepturus repens (Forst. f.) R. Br.

Wiry grass, at first an erect tuft, stems becoming geniculate decumbent and spreading, tufts tardily sending out elongate wiry stolons, rooting at nodes, whole plant glabrous except leaf margins very minutely scabrous, leaves broadly linear, at most 20 cm long, attenuate to a fine point, sheath equalling or shorter than blade, round on back; spikelets borne in elongate depressions on a cylindric jointed spike, arranged distichously on rhachis which has alternately diagonal articulations which disarticulate at maturity, each cylindric, grooved joint bearing one spikelet consisting of an ovate glume covering the groove in the rhachis joint, its apex prolonged into an acumen or awn, the lemma hyaline, fitting into the groove, enclosing the floret between it and a membranous palea, a small rachilla bearing a sterile floret between the fertile floret and the glume; at anthesis the glumes diverge from the spikelet, exposing the floret and the exserted anthers, the glume closes tightly later until maturity, when the spike disarticulates into cylindric joints, internally of dry aerogenous tissue which provides for dispersal by floating. The glume is minutely scabrous, which may aid in bird dispersal. The terminal node of a spike bears two glumes.

An ubiquitous species of shores and maritime situations throughout the Indo-Pacific region; on Maupiti very abundant, especially on motus.

Fosberg 64751 (US), 64810 (US), 64854 (US), 64971 (US)

Miscanthus Anderss.

Bunches of coarse culms with linear harsh leaves; panicle racemose-corymbiform, with many very hairy spicate-racemiform branches, spikelets very hairy, rhachis not disarticulating at maturity.

Miscanthus floridulus (Labill.) Warb. n.v. Sword-grass
Miscanthus japonicus Anderss.

Large clumps of culms to 2 or more m tall, leaves with scabrous cutting edges, panicle with prominent rhachis, many spike-like racemes of very pilose spikelets, when these are shed the filiform rhachises of the racemes persist, with short persistent pedicels.

A widely occurring Pacific island grass, forming savannas on many islands; on Maupiti dominant on very high eastern and southeastern slopes, occurring sporadically in forests and openings on lower slopes.

Fosberg 64799 (US); Morris 14 (US).

Oplismenus Beauv.

A small genus, of warm regions, of prostrate or decumbent grasses with short internodes, leaves broadly lanceolate to elliptic, thin, undulate, panicles racemoid, with spicate branches, few-flowered

broadly lanceolate to elliptic, thin, undulate, panicles racemoid, with spicate branches, few-flowered spikelets usually with short but conspicuous awns.

Usually growing in shady places, two species in Maupiti.

Oplismenus compositus (L.) n.v. 'ofe'ofe hu'a

Decumbent loosely branching grass with broad thin undulate elliptic leaves, panicles with branches over 1 cm long, divergent from rhachis, spikelets with muticous sterile lemma.

A common forest grass in Polynesia and Micronesia and westward, occasional on wooded slopes in Maupiti.

Raynal 17847 (p. 1338); Fosberg 64793 (US), 64823 (US)

Oplismenus hirtellus var. imbecilis (R. Br.) Fosb. & Sachet

Much smaller than O. compositus, forming thin open mats, leaves broadly lanceolate, panicle branches short, under 1 cm, spikelets crowded, tending to be reflexed, sterile lemma mucronate.

A widespread grass in Indo-Pacific region; common ground cover in lower slope forests on Maupiti.

Fosberg 64778 (US), 64801 (US)

Panicum L.
Brachiaria Griseb.

Grasses of various habit, leaves commonly broadly lanceolate, panicle either open-branched or of several spike-like racemes; spikelets uniflorous.

An enormous temperate and tropical genus, with a number of weedy species, especially in section Brachiaria (often treated as a separate genus). One species possibly exotic in Maupiti.

Panicum ambiguum Trin. n.v. nanamu ti'a rahi
Brachiaria paspaloides (Presl) Hubb.

Decumbent weak stemmed grass forming tangled masses loosely branched; sheaths rounded, hirsute, blades hirsute on both surfaces, linear, 10–20 cm long or more, ligule a close row of short erect bristles; fertile culms puberulent, well exserted; panicle with 2–4 divergent branches on a filiform rhachis, this very puberulent, rhachis of panicle branch flat but narrow, spikelets subsessile and shortly pedicellate, both on same raceme, spikelets elliptic, second glume and sterile lemma strongly 5-nerved.

Widespread tropical grass; in Maupiti of rare occurrence but widely distributed on motus in open coconut groves or cleared land.

Raynal 17861 (p. 1338); Fosberg 64855 (US); Fosberg & Sachet 64960 (US).

Paspalum L.

A large genus of tropical and temperate grasses of various habit, inflorescence of one to many spikes or spike-like racemes at or near the summits of erect or ascending culms, rhachis of individual spike usually broad and flat or with a median keel, spikelets uniflorous, flattened dorsiventrally, usually in 2 crowded rows on the rhachis, often disk-shaped. Several species in Maupiti.

Paspalum conjugatum Berg.

A pantropical weedy grass, occasional especially in more humid places on Maupiti.

Fosberg 64759 (US); Morris 30 (US), 31 (US).

Paspalum distichum L. n.v. salt grass
P. vaginatum Sw.

Decumbent, densely mat-forming grass, stems with many nodes, erect distally, sparingly branched above base; leaves smooth, margins not at all scabrous, arranged conspicuously distictiously, sheaths smooth, scarcely carinate, blades spreading-ascending, becoming inrolled, ligule membranous, truncate-obtuse; fertile culm erect, with 2 spikes, divergent at about 90°, rhachis with 2 rows of oblong-lanceolate flat spikelets, closely appressed to rhachis.

A pantropical and warm temperate zone grass, usually found in somewhat to strongly saline marshes; in Maupiti forming dense stands on flats that are occasionally flooded by sea-water.

Fosberg 64929 (US).

Paspalum orbiculare Forst. f.

Loosely caespitose perennial, culms slender but stiff, purplish at base, lowest sheaths without blades, more distal ones tightly clasping culm, blades narrow, elongate, upper ones falling somewhat short of equalling culm, blade somewhat scabrous on margins, tapering to a very slender tip, ligule very short, truncate, stiff membranous, with abundant short stiff hairs on outer surface; culm slender with 3–4 remote deflexed spikes about 2–2.5 cm long, rhachis of spike narrow, with 2 rows of suborbicular crowded spikelets, these with outer face (sterile lemma) with 3 nerves, the outer submarginal; stigmas exserted, dark purple.

A common widely distributed weedy grass throughout the Pacific islands, found on bare soil and often common in moist places; occasional in open places on Maupiti.

Fosberg 64788 (US).

Paspalum paniculatum L. n.v. 'ofe'ofe

Culoms tall or spreading, leaves thin, panicles of many racemes.

A widespread weedy grass, on Maupiti very local in disturbed places, doubtless introduced.

Raynal 17862 (p. 1338); Fosberg 64845 (US); Morris 27 (US).

Schizostachyum Nees

A small genus of bamboos, one species of which is widespread in the south Pacific, including Maupiti.

Schizostachyum glaucifolium (Rupr.) Munro

A large woody bamboo, to 15 m tall, internodes 3–5 dm long, walls rather thick (2–4 mm) and strong, green, culms forming loose clumps. Seldom, if ever, found flowering.

In most high Polynesian islands, on Maupiti rare, small colonies on wooded slopes, probably carried by Polynesians, used by them for many purposes.

Morris 11 (US)

Sporobolus R. Br.

A medium-large genus of tropical and warm temperate grasses with branched panicles varying from strict to diffuse, spikelets uniflorous, pedicellate. One species, probably introduced, in Maupiti.

Sporobolus fertilis (Steud.) Clayton

Sporobolus indicus var.

Tufted, panicle elongate, branches closely appressed, spikelets small.

Widespread weedy species, occasional locally in open places on Maupiti.

Fosberg 64802 (US), 64889 (US, BISH), 64922 (US).

Thuarea Pers.

A widespread genus of strand grasses, prostrate, monoecious, probably only one or two species, one in the Pacific islands including Maupiti.

Thuarea involuta (Forst. f.) R. & S.
Ischaemum involutum Forst. f.
Thuarea sarmentosa Pers.

Prostrate, somewhat fleshy creeping stems rooting at nodes, forming loose mats, flowering stems short, erect, flowers unisexual, lower florets in spikelet pistillate, upper staminate, these early deciduous, lower pistillate, enclosed by a broad rhachis, in fruit forming a hard small "fist-like" floating structure containing the fruit or caryopsis.
A widespread Indo-Pacific strand grass, seen only very locally on motus in Maupiti.
Fosberg 64848 (US).

Tricholaena Schrad.
Rhynchelytrum Nees

A small African genus of weedy grasses, one of which has spread through the tropics, partially, at least, because of its ornamental qualities.

Tricholaena rosea Nees n.v. Natal red-top
Tricholaenpa repens sensu auct. non T. repens (Willd.) Hitchc.
Rhynchelytrum repens sensu auct. non R. repens (Willd.) Hubb.

Slender erect grass, often behaving as an annual, panicle open, fuzzy with long red hairs, these sometimes fading when old.
Widely introduced and naturalized grass, native of South Africa; in Maupiti occasional to common along roadsides.
Fosberg 64921 (US).

CYPERACEAE

Grass-like plants, but with usually solid, often triangular stems, spiralled arrangement of leaves, sheaths closed, spikelets usually with many scale-like bracts, spirally or distichously arranged, fruit a nut, often called an achene, with one erect seed free from ovary wall.

Cladium P. Br.

A small genus of sedges found in most warm countries, growing in marshes. The most modern treatment of this genus, by Kern, in Flora Malesiana I, 7:688-690, 19, places the entire genus in one species, a course that is being followed here.

Cladium mariscus (L.) Pohl n.v. saw grass
Cladium jamaicense Crantz
Cladium jamaicense var. chinense (Nees) Koyama

Dense stands of erect leafy culms, to 1.8 m, spreading by underground rhizomes, rhizome 3–4 mm thick, arching downward from root crown, then turning up erect, new ones from arching one, then either creeping or turning up; leaves with closed sheaths, sinus deeply V shaped with lowest margins over-lapping, blade to 1 cm wide, carinate dorsally, canaliculate above, elongate, tapering gradually to a long flagelliform scabrous point, keel and margins antrorsely appressed spinulose-scabrous; panicle to 25 or more cm long, interrupted, composed of 2–6 or more pedunculate, bracteate sub-panicles, these branched several times, each branch ending in a glomerule of sessile spikelets, these uniflorous

with 3 style branches, scales several, spirally imbricate, chestnut brown, spikelet ovoid.

Pantropical species with several geographical subspecies, dominating many tropical and subtropical marshes; in Maupiti forming large pure stands in low wet spots in motus.

Fosberg & Sachet 64958 (US); Fosberg 64975 (US).

Cyperus L.

Plants with basal leaves and solitary or caespitose terete to sharply triangular culms, these unbranched and bearing at their summits an inflorescence varying from simply capitate to umbelloid-spicate to several times compound aggrations of compressed spikelts, subtended by leaf-loke bracts usually graduated in size, the distal ones smaller. A practically cosmopolitan genus of many species.

Cyperus compressus L. n.v. mo'u upo'o taratara (cyperacee a tete herissee)

Annual (?), small tufts, spikelets flat, elliptic, green.

Widespread weed, rare on Maupiti.

Fosberg & Sachet 64961 (US).

Cyperus cyperinus Retz. n.v. mo'u upo'o (cyperacee a(grosse) tete)

Mariscus cyperinus (Retz.) Vahl.

Slightly caespitose inflorescence, an umbell of heads of ascending slender spiklets.

Raynal 17828 (p. 1337). Widespread weed, found once on Maupiti, not seen in 1985.

Cyperus cyperoides L. n.v. mo'u upo'o taratara

Mariscus sumatrensis Retz.

Similiar to C. cyperinus but spiklets at right angles to rhachis or slightly reflexed.

A very widespread weedy species, found once on Maupiti but not seen in 1985.

Raynal 17821 (p. 1337)

Cyperus javanicus Houtt. n.v. mo'u taviri ha'ari

Mariscus pennatus (Lam.) Merr.

Coarse caespitose smooth culms, with 10 – 12 gray-green linear long-tapering leaves about 1 cm or less wide, channel-like on upper surface, broadly carinate beneath, margins and, to some extent, keel sharply scabrous umbellate, subtended by 5 strongly unequal leaf-like bracts, longest exceeding lm, rays strongly spreading, with 8 or more divaricate to reflexed spike-branches, sessile patent or slightly reflexed, light brown, lanceolate, compressed, acute, 5 – 9 mm, about 4 scales overlapping on each edge; dark brown sharply trigonous, ovoid, pointed.

A widely distributed Pacific lowland and strand species, found in all Pacific island groups.

Fosberg 64749 (US), 64884 (US); Raynal 17826 (p. 1337).

Cyperus kyllingia Endl. n.v. mo'u upo'o' uo'uo/no'ano'a

Kyllinga nemoralis (Forst.) Dandy.

Small tufted sedge, leave mostly basal, spikelets crowded in small white heads.

Widespread weed, locally established in village.

Raynal 17819 (p. 1337); Fosberg, sight in 1985.

Cyperus polystachyos Rottb.

Tufted, linen lanceolate flat spikelet in subcapitate clusters.

Common weed in wet places especially in interior of motus.

Fosberg 64757 (US), 64959 (US).

Cyperus rotundus L. n.v. nut-grass

A most persistent garden-weed throughout the tropics; occasional in Maupiti.
Fosberg 64844 (US)

Fimbristylis Vahl

Usually slender, often more or less tufted, wiry plants, stems round with leaves basal or only in lower part, or lacking, inflorescence a single spikelet subtended by a bract or more usually an umbelloid assemblage, simple or compound, or reduced to a head, usually subtended by bracts; spikelets with scales spirally arranged, or rarely more or less compressed and scales in 2 ranks, stamens with flat filaments, linear anthers; style usually more or less flattened, often with the edges strongly fimbriate or ciliate especially above, 2 or 3, rarely more, linear stigmatic branches; nut biconvex or trigonous, often obovate, style caducous without leaving a persistent enlarged or bulbous base.

A large mostly tropical genus of sedges, found in various, often moist, habitats; one species known from Maupiti.

Fimbristylis cymosa R. Br.

Caespitose acaulescent herb with bright green coriaceous narrowly linear leaves with short, firm dark brown open sheaths tightly crowded at base, blades ascending to spreading, midrib none, apex abruptly acute; scape ascending to erect, terete, slightly ribbed, completely leafless; inflorescence from capitate to open, umbelloid, subtended by 2-several leaf-like bracts with broad brown sheaths, subulate short blades, not usually exceeding branches, branching very congested to open, if open, with a sessile spikelet at each ramification, or several such, ultimate branchlets bearing either a spikelet or a glomerule or head of spikelets; spikelets ovoid to rarely cylindric, obtuse, scales spirally imbricate, ovate, obtuse to rounded at apex, cinnamon brown center with broad scarious margin; style not at all fimbriate, base enlarged, branches 2 (in ours), recurved, bristles (filaments?) 2, achene dark brown, smooth, obovoid, plump, somewhat planoconvex.

A pantropical extremely variable species, with a number of subspecies and/or varieties which have not yet been satisfactorily defined. In stature the plants vary enormously, also in degree of openness of inflorescence. Even the number of style branches varies. On Maupiti the plant is very abundant on the motus. It stands trampling very well and is a principal component of lawns around dwellings.
Fosberg 64880 (US), 64887 (US), 64888 (US), 64973 (US), 64974 (US)

ARECACEAE (PALMAE)

Trees or shrubs with columnar trunks, rarely branched except at base, a crown of often enormous simple or pseudo-compound leaves, flowers usually in panicles, fruit drupaceous or berry-like, seed with fleshy or bony endosperm.

Cocos L.

Tall trees with a hard but elastic trunk (swaying in wind), ringed with leaf scars, crowned with enormous pinnate leaves.

Genus now restricted to a single species.

Cocos nucifera L. n.v. coconut niu

A tall robust tree with a columnar unbranched trunk, ringed with leaf scars, bearing a crown of enormous pinnately compound leaves several meters long, the leaflets linear with the fold /\-shaped; flowers borne in axillary panicles enclosed in boat-shaped woody bracts, monoecious, the staminate borne on the distal portions of the .ta1
panicle, the pistillate much larger and in the basal parts of the panicle; the fruit an enormous

triangular-ovoid drupe with a fibrous mesocarp surrounding a thin hard endocarp or shell; endosperm white, oily, forming a layer 1_1.5 cm thick on inside of shell, surrounding a large cavity containing a watery fluid; embryo small, fusiform, embedded near one of three thin spots on the proximal end of the endocarp; the enlarged calyx surrounds the attachment to the panicle branch.

This is the coconut, one of the most useful of all plants, now found throughout the tropics, carried by man or by floating, from a probable Indian Ocean origin. Much controversy has surrounded the origin of this plant, as no truly wild plants are known that could not have been carried by man. Practically all parts of the plant are used by indigenous peoples throughout the Indo-Pacific region. Copra, the dried endosperm, is an important commercial crop, being the source of coconut oil, used in soap-making and for food oils and fats.

Fosberg, sight record.

ARACEAE

Family unusual in Monocotyledonae in its usually net-veined leaves, flowers in dense fleshy spikes often without perianth, sometimes 4-merous, spike usually subtended or surrounded by a large bract called a spathe.

Alocasia G. Don

A medium sized Indo-Malaysian genus of thick-stemmed herbs, a weaker lateral vein between each pair of principal lateral veins; spathe with a lower part that thickens and persists, an upper "blade" that withers and falls off; spadix with a zone of pistillate flowers below, separated from and above it a zone of staminate flowers, then a roughened sterile appendage; fruit a red berry. One species common in Society Islands, seen in Maupiti.

Alocasia macrorrhiza (L.) G. Don

Erect herb with thick starchy trunk, bright glossy green leaves, blade sagittate with basal sinus reaching petiole, basal lobes rounded, lateral veins thick, submarginal vein close to margin, spathe with lower 3-5 cm persistent, upper 20 cm withering, spadix pistillate near base, then staminate, above this, then a long sterile appendage.

Common throughout Polynesia, not abundant on Maupiti.

Fosberg, sight record.

Colocasia Schott

A small Old World tropical genus with tuberous corm; flowers monoecious, stamen forming synandria. Noted for containing the taro or dasheen.

Colocasia esculenta (L.) Schott n.v. taro; dasheen; coco-yam

Acaulescent but with a large swollen starchy corm; erect long-petiolate leaves with glaucous, sagittate, vertically hanging peltately attached blades; rarely seen flowering.

Planted for its edible corms, an important food plant, grown to some extent in Maupiti.

Fosberg, sight record.

Cyrtosperma Griff.

A small genus of thick-stemmed or tuberous herbs, petioles often prickly, plants often reaching a great size; leaves sagittate or hastate, spathe persistent, somewhat exceeding spadix, perianth present.

Mostly developed in New Guinea. One species widespread in Pacific islands.

Cyrtosperma chamissonis (Schott) Merr. n.v. puraka

Large plants, stem tuberous to somewhat elongate and erect; leaves erect, basal lobes and apex acute or acuminate, blade bright green, petiole usually but not always prickly.

Widely planted for its edible corm, often grown in marsh culture, very rare in Maupiti, found once in an upland valley.

Morris 16 (US)

Xanthosoma Schott

Large acaulescent or nearly acaulescent plants with thickened or tuberous starchy corm, glaucous leaves, sagittate with sheath extending well up petiole, spadix fertile to apex.

A tropical American genus with one or two species in cultivation in Pacific islands, one seen in Maupiti.

Xanthosoma sagittifolium (L.) Schott n.v. yautia

Native of tropical America, widely cultivated in the tropics, and in many Pacific islands, including Maupiti, for its edible corms.

Fosberg, sight record.

COMMELINACEAE

Small or medium sized mostly tropical family, mostly herbs with succulent stems, alternate leaves, usually with well-developed sheaths, cymose inflorescence of 3-merous flowers, fruit a loculicidal capsule or indehiscent.

Commelina L.

Small herbs, usually blue-flowered, corolla fugaceous.

One species in Maupiti.

Commelina diffusa Burm. f. n.v. ma'a pape day-flower

A common tropical weed, found on slopes in disturbed or cultivated ground in Maupiti.

Raynal 17863 (p 1338); Gillette 1 (US), 5 (US) Fosberg 64953 (US)

Rhoeo Hance

An acaulescent purple herb with large rosettes of oblong-lanceolate leaves, boat-shaped inflorescence bracts, white flowers.

A genus of one species, originating in the Caribbean - Middle American region, widely cultivated in the tropics.

Rhoeo spathacea (Sw.) Stearn

Rhoeo discolor (L'Her.) Hance.

Seen only as a pot-plant on Maupiti.

Fosberg, sight record.

BROMELIACEAE

Large mostly tropical American family of herbs, typically but not always funnel-shaped, rosettes, frequently epiphytic, a few species are widely cultivated in the tropics, especially the pineapple.

Ananas Mill.

Rosettes of linear-lanceolate, commonly prickly-margined leaves, terminal spicate inflorescences,

crowded and fleshy, after flowering producing a terminal secondary rosette or crown of leaves.
South American, but one species pantropical in cultivation.

Ananas comosus (L.) Merr. n.v. pinapo; pineapple

Planted food plant, fruting spike enlarged, fleshy, edible.
Fosberg 64945 (US).

LILIACEAE
(sensu latissimo including Agavaceae, Amaryllidaceae, etc.)

Very large cosmopolitan family, with simple, alternate leaves, and usually 6-merous flowers, many of them very showy.

Cordyline R. Br.

Erect sparsely branched shrubs with spirally arranged, pinnately parallel-veined leaves, terminal panicles of rather small flowers, ovary superior, fruit a few-seeded berry.
Several Pacific species, one widespread, ethnobotanically important.

Cordyline fruticosa (L.) Chev. n.v. auti
Cordyline terminalis (L.) Kunth

Erect sparsely branched thick-stemmed shrub with an enlarged edible root, young stem tissue physiologically active; leaves large, arranged spirally in 2 or 3 somewhat indefinite ranks on upper portion of stem, blade elliptic about 3_6 dm long, abruptly acuminate, veins pinnately parallel with a strong midrib, continued at base in a wide petiole, channelled above; flowers in a recurved axillary panicle with a definite rhachis with ascending spicate branches, flowers whitish or purplish, limb 6-parted, subtended by 1_3 scale-like bractlets, fruit a firm globose berry, red externally with white flesh and up to 6 shiny black seeds of irregularly hemispheric shape.

Probably native to the western Pacific, carried by Polynesians to the eastern island groups, used for many purposes, the root baked for food, leaves for wrapping food for cooking, also for spreading food for feasts, for hula skirts, etc. Many cultivars with colored leaves exist. In Maupiti the colored forms are planted as ornamentals. The large leafed green form is naturalized on wooded slopes, especially around ancient terraces and other remains, but is seldom seen flowering or fruiting.
Fosberg, sight record.

Crinum L.

Large herbs, acaulescent from tunicate bulbs, rosettes of large, spirally arranged leaves, these usually lanceolate, trough-shaped, bases forming a "neck"; inflorescence a scape bearing an umbel or head of flowers subtended by two spathe-like bracts, ovary inferior, perianth of 6 more-or-less equal segments, united in lower part into a tube; seeds fleshy, produced in a fleshy dehiscent or indehiscent capsule.
Many species, in both hemispheres, some cultivated as ornamentals, identification difficult, as there are many horticultural forms.

Crinum asiaticum L.

(A large green leafed form not seen in flower).
Planted ornamental.
Fosberg, sight record.

Hymenocallis Salisb.

Acaulescent herbs, resembling Crinum but leaves distichous, and filaments united at base by an expanded membranous web.
Tropical American. but widely cultivated, occasionally naturalized.

Hymenocallis littoralis Salisb. n.v. spider-lily

A planted ornamental, sparingly naturalized on Maupiti.
Gillette 11 (US).

Sansevieria Thunb. n.v. bowstring hemp

Acaulescent plants from tough congested rhizomes, leaves thick, from flat to canaliculate to terete, with very strong fibers; inflorescence a spike or narrow raceme or panicle, of six-merous, tubular flowers; fruit a berry.

Sansevieria trifasciata Prain n.v. snake-plant; mother-in-law's tongue
law's tongue

Planted ornamental, tending to persist.
Fosberg 64938 (US)

DIOSCOREACEAE

A large mostly tropical family, of few genera, of twining climbers, with alternate or opposite, rarely whorled, net-veined, often strongly nerved leaves, 6-merous small flowers, dioecious, ovary inferior.

Dioscorea L.

Twiners, from a thick, short rhizome or more usually a tuber, some producing tubers also on aerial stems, leaves simple or rarely apparently compound, palmately nerved; inflorescence a spike or spicate panicle; flowers small, fruit a 3-angled or usually 3-winged capsule.
Many species, some very widely cultivated for their edible starchy tubers, at least 3 species in Maupiti.

Dioscorea alata L.

Stems 2_4_winged, twining to right, not prickly; leaves opposite, ovate-cordate, thin, petiole curved at base, subterranean tubers large, edible, subaerial ones rare, small; capsule broader than long.
A common cultivated yam, found once on Maupiti.
Gillette 8 (US).

Dioscorea bulbifera L.

Smooth-stemmed, twining to left, leaves large, orbicular-cordate, sinus wide, tubers mostly aerial, axillary potato-like, mostly inedible.
A very widely distributed species, rare on Maupiti in thickets on lower slopes.
Fosberg 64816 (US), 64820 (US).

Dioscorea pentaphylla Forst. f. n.v. patara

Plants pubescent, glabrate, stems twining to left, tubers mostly sub-terranean, in wild plants inedible, leaves pseudo-compound, trifoliolate or usually pentafoliolate.
A widespread Pacific species, once found on Maupiti, but not found in the 1985 survey.
Raynal 17850 (p. 1338)

TACCACEAE

A monogeneric family of a few tropical species, herbs from rhizomes or tubers.

Tacca Forst.

Acaulescent, leaves erect, long-petioled, entire or lobed; inflorescence scapose, an involucrate umbel of small flowers with inferior ovaries; fruit many-seeded.

A very few species, one very widespread in the Pacific islands, including the Society Group, frequent on low coral islands.

Tacca leontopetaloides (L.) 0. Ktze. n.v. pia
Tacca pinnatifida Forst.

Acaulescent herb to 1.5 m tall, usually 1-several leaves and 1_2 scapes erect from base, bearing starchy potato-like underground tubers; leaf with 3-parted blade at summit of cylindric striate hollow petiole 1.5_3.0 cm thick, to 90_100 cm tall, blade alternately dichotomously palmatifid, each primary segment twice dichotomous, each rhachis winged, each blade segment deeply lobed, the main veins alternately dichotomous, lobes broadly ovate, strongly acuminate, pinnately veined, with conspicuous network between veins, lobes tending to be bilobed, main segments to 50 cm long, ascendigly divergent, veins prominent beneath, impressed above, central segment pinnately divided, lateral ones once evenly dichotomous, then each part alternately dichotomously pinnatifid; scape terete, striate, hollow, tapering from base, 1.2 cm, to summit, 1 cm diam., expanded at summit to a thick disk-like solid "receptacle", surrounded by an involucre of 6_7 foliaceous bracts in 2 concentric series on margin of receptacle, many pedicels and a smaller number of filiform bracts to 15 cm or more long arise from the low convex upper surface of receptacle, pedicels 4_4.5 cm long, each bearing a flower, some of which develop into fruits, a majority not, perianth parts 6, in 2 series, one broad, one narrow, leathery, ovate, inrolled and becoming incurved, each bearing a stamen at its base, stamen wide, strongly hooded or pouch-shaped, white, fleshy; ovary inferior with a raised disk bearing 3 bilobed fleshy transparent stigmas, ovary 1_loculed, with ovules borne on 3 fleshy parietal placentae; fruit an ovoid-subglobose berry with 6 longitudinal ridges, truncate apex with 6 persistent sepals, many brown longitudinally ribbed ellipsoidal to nearly orbicular seeds embedded in a fleshy pulp. A widespread Indo-Pacific species, with remarkable morphology, possibly carried around by Polynesians, as its tubers were used by them as food. Common on motus of Maupiti.

Fosberg 64972 (US).

ZINGIBERACEAE

Herbs, often large, often aromatic, stems from thick fleshy rhizomes or tubers, leaves alternate, sheathing, flowers trimerous, ovary inferior, flower-parts often variously modified, fruit capsular, seed often arillate. A large tropical family with many ornamentals, a few economic species.

Alpinia Roxb.

Large leafy herbs, leaves pinnately parallel-veined; inflorescence usually terminal, spicate, racemose or paniculate, often bracteate, flowers trimerous, perianth in 2 series, each united, usually tubular and 3-lobed.

A large Old-World tropical genus with a number of ornamental species, one planted in Maupiti.

Alpinia purpurata (Viell.) K. Schum. n.v. red ginger

A tall ascending leafy herb, flowers white, in large spikes with conspicuous red bracts; small plante often arising viviparously in axils of bracts.

Planted ornamental.

Fosberg, sight record.

CANNACEAE

Large perennial herbs; leaves large, alternate, pinnately parallel-veined; flowers trimerous, fertile stamens reduced to 1/2 of 1 stamen, the rest are expanded and showy staminodia, fruit a 3-loculed tuberculate capsule.

A monogeneric tropical family.

Canna L.

A small genus of coarse herbs, usually somewhat showy flowers, ovary inferior.

One introduced species in Maupiti.

Canna indica L. n.v. re'a pua'aniho Indian shot

Widespread in the Pacific islands, probably persisting from cultivation either for its rhizomes which may be edible, or for its scarlet flowers.

Raynal 17830 (p. 1337); Fosberg 64833 (US)

ORCHIDACEAE

An enormous cosmopolitan but mainly tropical family, mostly herbaceous, but with great diversity in habit; flowers exhibiting an incredible variation based on a pattern of 3 similar sepals, 3 petals, the lower one modified into an expanded organ called a lip, stamens and pistil fused into a column with pollen united into masses called pollinia, a stigmatic surface, ovary 1 celled, inferior, all adapted for very specialized insect pollination.

Four genera known from Maupiti, plus several potted Dendrobium species not identified.

Oberonia Lindl.

Epiphytic small herb with distichous equitant leaves and racemes of tiny white flowers. One species reported from Maupiti.

Oberonia equitans (G. Forst.) Mutel
(O. glandulosa Lindl. ?)

Leaves alternate, vertically oriented in a single plane. Found once on Maupiti but not seen on 1985 survey.

Raynal 17854 (p. 1338).

Spathoglottis Bl.

Terrestrial, with large pseudobulbs, giving rise to stiff strongly plicate leaves, scapes with racemes of showy flowers with 3-lobed lip with 2 calli. A south-east Asian, Australian and Pacific genus with one species probably introduced on Maupiti.

Spathoglottis plicata Bl.

Flowers medium sized, bright rose-purple.

Native of Western Pacific and S. E. Asia, widely naturalized in Pacific islands, on Maupiti rare and scattered at least on S. part of Motu Auira.

Fosberg 64871 (US), Fosberg & Mount 64882 (US), 64883 (US).

Taeniophyllum Bl.

Leafless and almost stemless herbs, photosynthetic roots radiating from an extremely condensed stem (crown), flowers minute, cream-white, in bracteate spike-like racemes. A large S.E. Asian, Malayo-Pacific genus, one species known from Maupiti.

Taeniophyllum fasciola (Forst. f.) Seem. n.v. fe'e 'uru

Photosynthetic roots pale-green, flattened, epiphytic on large branches, flowering racemes several, lip saccate or with broad blunt spur. Found once on Maupiti, but not seen in 1985 survey.
Raynal 17825 (p. 1337).

Vanilla Mill.

Climbing, twining vine-like, with well-separated lanceolate thick leaves, greenish flowers; fruit terete, pod-like elongate. Many species in the tropics.

Vanilla planifolia Salisb. n.v. Vanilla

The plant yielding commercial vanilla "beans", probably native of tropical America, in Maupiti naturalized or more likely persisting, at fairly high elevations, from former cultivation.
Fosberg 64780 (US); Morris 3, (US).

DICOTYLEDONAE

CASUARINACEAE

Trees with cylindrical, articulate, striated green branchlets which serve as leaves; the true leaves reduced to whorls of minute scales at the nodes; flowers monoecious or dioecious, much reduced, without perianth, arranged in aments, wind pollinated, the staminate aments cylindric, articulate; pistillate aments capitate, developing into woody cone-like structures formed from thickened indurate floral bracts; fruit a samara with a single wing.
A family of a single genus (by some regarded as two), principally Australasian.

Casuarina L.

Characters of the family.
A small genus, principally Australian, with several species in New Caledonia, New Guinea, and Malesia, one widespread in the Indo-Pacific region, and generally introduced in the tropics and subtropics.

Casuarina equisetifolia L.

Tree, reaching a large size, heart-wood very hard and heavy; branchlets jointed, joints about 1 cm long, about 1 mm or less thick, with 6_8 striae; leaves in whorls of 6 to 8; flowers monoecious to dioecious, staminate in cylindric elongate aments, pistillate in shorter turbinate aments, styles maroon, filiform, fruiting aments cylindric to globose, about 1_1.5 cm thick, up to 2 cm or more long; fruit with a transparent wing.
Widespread Pacific island tree, on Maupiti common locally, especially interiors of motus.
Fosberg & Sachet 64969 (US).

PIPERACEAE

Shrubs, vines or herbs; leaves simple, entire, alternate, opposite, or whorled; flowers in spikes or racemes, much reduced, without perianth, but each subtended by a peltate bract, or surrounded by 3 bracts, perfect or unisexual; stamens 2 or more, anthers usually 2-celled; ovary 1-celled with 1 basal

ovule, stigmas 1 to several, sessile; fruit a drupe or a minute sticky nut.

A pantropical family found in many habitats but common in forest undergrowth, epiphytic, and on rocks.

Peperomia R. & P.

Herbs, usually fleshy; leaves alternate, opposite, rarely whorled, with palmate venation, petioles expanded or not at base; spikes terminal, leaf-opposed, or axillary, fleshy, lower leaves on stems often reduced; flowers bisexual, reduced to an ovary and two stamens subtended by a stalked peltate bract; fruit a very sticky minute nut or nut-like drupe (usually described as a berry).

Pantropical, with a number of ill-distinguished species. Common in moist or wet forests, epiphytic or terrestrial, especially on rocks.

Peperomia blanda (Jacq.) Kunth in H.B.K. n.v. piripapa
Peperomia leptostachya H. & A.

Erect, fleshy, pubescent herb, leaves opposite or whorled, lower ones tending to be reflexed and caducous in dry seasons and situations, oval, oval-obovate, or rarely broadly ovate, obtuse to acutish or rounded at both ends, petioles up to 1 cm long, usually shorter; spikes terminal or in upper axils, pedunculate, slender, elongate, to 6 (or 10) cm or more, peduncles hirtellous, rachis glabrous; fruit globose-subobovoid, 0.9 mm long.

Hawaii and Southeastern Polynesia westward at least to Fiji and the New Hebrides.

Fosberg 64893 (US); Morris 2 (US), 23 (US).

Peperomia tahitensis Yuncker ?

Decumbent to rarely erect, rooting at least at lower nodes, stems shortly pilose, leaves opposite, sparsely pilosulous, dark punctate, obovate, obtuse, usually palmately 3-nerved, margins ciliate, petioles to 1 cm, usually shorter, pilose; spikes terminal and axillary, pedunculate, peduncle hirsute, much longer than leaves, rhachis glabrous, fruit minute, sticky.

A Society Islands endemic, known from Tahiti and probably from Maupiti, though specimens seen from Maupiti are sterile. Here it grows on great basalt boulders.

Raynal 17834 (p. 1337); Fosberg 64896 (US); Gillette 6 (US).

MORACEAE

Lactiferous trees, shrubs, occasional vines; leaves simple, alternate, stipulate; flowers cymose or in heads or on fleshy receptacles, commonly much redued, perianth one series, usually unisexual and monoecious; fruit an achene or drupe, often fused into fleshy multiples.

A large family, mostly tropical, many genera important economically or ecologically. Two genera are in Maupiti, possibly one or two more cultivated.

Artocarpus Forst.

Large trees with large simple often lobed leaves, sheathing stipules, flower closely packed on fleshy receptacles, staminate and pistillate separately; fruit a large fleshy edible syncarp. The breadfruit and jak-fruit belong to this genus.

Artocarpus altilis (Parkinson) Fosberg n.v. breadfruit; uru
Artocarpus communis Forst.
Artocarpus incisus (Thunb.) L. f.

Robust tree to 25_30 m tall, branchlets ringed with stipule-scars; leaves alternate, large, to 2_3 dm long, ovate to obovate deeply (or rarely slightly) lobed or incised, strongly pinnately veined, glossy above, with a strong petiole; flowers monoecious; staminate in large club-shaped terminal spikes,

crowded tightly together, pistillate in dense heads borne terminally on branches, fused together, surface of mass bearing styles, the head enlarging to a globose or subcylindric syncarp, the surface covered by low pyramidal Polygons, the interior a fleshy mass usually without seeds.

This tree, with edible fruits, is an important source of food throughout the Indo-Pacific region. Its native home unknown, but possibly New Guinea, where it may have originated by hybridization of two or more wild species. There are many cultivated varieties, with different local names. It is an important food plant in Maupiti as well as the other Society Islands.

Fosberg 64946 (US).

Ficus L.

Trees, shrubs, rarely creepers; leaves simple, stipules usually sheathing terminal bud, leaving a ring-like scar around stem when fallen; flowers on the inner surface of a fleshy pouch-like enlarged receptacle; fruit a very small hard seed-like achene, borne in large numbers in the cavity of the receptacle. One native species and two exotic ornamentals in Maupiti.

Ficus microcarpa L.f. n.v. Chinese banyan

Ficus retusa L.

A banyan-type tree with aerial roots well devoloped; small, obovate or elliptic leaves, sessile paired small figs.

Planted ornamental.

Fosberg 64866 (US).

Ficus benjamina L. n.v. weeping fig

A wide spreading tree without aerial roots, branchlets slender and drooping, leaves small, elliptic, acuminate, figs yellow.

Planted ornamental.

Fosberg 64935 (US).

Ficus prolixa Forst. f.

A native Pacific island banyan-type fig, widespread in the south west Pacific islands; present but uncommon on wooded slopes and ridges in Maupiti.

A "banyan type" tree, with many hanging aerial roots which become supplementary trunks, leaves oblong, somewhat acuminate; figs small, globose, sessile in pairs at nodes, purplish-black when ripe.

Fosberg 64772 (US); Morris 15 (US).

AMARANTHACEAE

Large family, with many weedy species, as well as local species, not strongly represented in Pacific islands except in Hawaii. Flowers generally small, perianth of one series, segments often scarious; fruit a utricle.

Alternanthera Forssk.

A large genus, principally tropical, of herbs or sub-shrubs, some weedy, a few cultivated, leaves opposite, flowers in axillary, rarely terminal, heads, bracts scarious, overlapping; stamens united in a tube with staminodes between them. One cultivated species in Maupiti.

Alternanthera brasiliana (L.) 0. Ktze.

Alternanthera dentata (Moench) Fries

A slender herb with maroon-purple leaves and pedunculate white heads.

Planted ornamental.

Fosberg 64927 (US).

Gomphrena L.

A genus of herbs, mainly tropical, several weedy and cultivated species widely introduced. Leaves opposite, flowers in dense heads with chaffy colored or white bracts and perianth, stamens united into a tube. At least two species are introduced in the Pacific islands.

Gomphrena globosa L.

A small bushy herb with white or bright pink flower heads.
Planted ornamental.
Fosberg 64930 (US).

POLYGONACEAE, n.v.Buckwheat family

A cosmopolitan, very distinct family of diverse habit. Leaves simple, alternate, usually with tubular sheathing stipules (ocreae), one series of petaloid perianth segments, a 1-locular ovary with 1 basal ovule; fruit an achene, often trigonous.

Antigonon Endl.

A very small genus of climbers, part of the inflorescence modified into a tendril. Native to Mexico and Central America, one species widely cultivated.

Antigonon leptopus H. & A.

A climber with panicles of bright pink flowers.
Planted ornamental.
Fosberg 64926 (US).

NYCTAGINACEAE

Herbs, shrubs, trees, scramblers; leaves and branching alternate or usually opposite, leaves simple, flowers with one series of united, usually corolloid perianth parts, few stamens basally inserted, ovary 1-celled, fruit an anthocarp, an achene enveloped in the persistent lower part of the perianth. Widely distributed mostly in warm countries.

Boerhavia L.

A widely distributed genus of herbs, some slightly woody, leaves opposite, flowers mostly small, perianth strongly constricted near middle, upper part petaloid, lower part ribbed, becoming the anthocarp. A number of ill-distinguished species, one locally common in Maupiti.

Boerhavia tetrandra Forst. f.

Prostrate glabrous herb, several elongate stems radiating from a much-thickened rootstock, internodes slightly falcate; leaves oblong to suborbicular, white beneath, flowers pink, in cymes on axillary peduncles, cymes from open to glomerate, anthocarps 5-ribbed, ellipsoid or clavate, sticky-glandular, several mm long.

Widely distributed Polynesian and Micronesian species, especially common on atolls and coral motus, on Maupiti found locally on motus in rather open situations.

Fosberg 64868 (US)

Bougainvillea Comm. ex Juss.

Woody climbers or scramblers, often with a single stout spine at each node; leaves alternate; flowers usually 3 in a group, subtended by and adnate to 3 showy bracts; perianth tube slender, somewhat constricted, with a short spreading limb, native of South America, very common as ornamentals throughout the tropics and subtropics, with many horticultural forms and cultivars.

Bougainvillea glabra Choisy

Tangled climber, leaves elliptic acuminate, flowers magenta.
Several cultivars of this species planted on Maupiti, along with one or two which may be B.×buttiana Holtt. & Standl.
Fosberg, sight record.

PORTULACACEAE

Herbs, mostly succulent, leaves alternate or opposite, stipulate; sepals 2, petals 4_5, ovary 1-celled with central basal placentation. Cosmopolitan family, some species are familiar weeds.

Portulaca L.

Herbs with very fleshy leaves on somewhat to very fleshy stems; stipules usually modified to an axillary tuft of hairs; ovary semi-inferior; capsule circumscissile, seeds spiral-pyriform, variously sculptured. A large genus, practically world-wide in distribution; 2 species known from Maupiti.

Portulaca johnii v. Poelln.

Very fleshy reddish stems, robust plant, decumbent, leaves obovate, fleshy, flowers yellow, 2 cm across, opening mid-morning, stamens 25_35.
This is locally common on the motus of Maupiti.
Fosberg 64850 (US).

Portulaca oleracea L.

Flowers open at 8 a.m., closed by mid-morning, about 1 cm or less across, petals yellow, suborbicular, slightly emarginate, stamens about 12.
Cosmopolitan species, locally common in open disturbed places on Maupiti, possibly native.
Fosberg & Sachet 64968 (US); Fosberg 64804 (US), 64910 (US)

Talinum Adans.

Small tropical genus, habit various, flowers in terminal cymes or panicles, fruit a 3-valved capsule. One pantropical species occurs in Maupiti.

Talinum paniculatum (Jacq.) Gaertn.

Herbaceous stems, bare below, with spatulate or oblanceolate leaves rather crowded above; terminal open panicles of pink flowers; fruit a thin ellipsoidal capsule.

Talinum patens (L.) Willd. n.v. 'aturi
Pantropical species, rare on Maupiti, found on rock-ledges at upper elevations.
Raynal 17818 (P) (p. 1337); Morris I (US).

ANNONACEAE

Woody plants, habit various, leaves alternate, simple, exstipulate; flowers usually trimerous,

perianth segments in 2 or more series, stamens many, carpels many, free or partly so, often becoming fused in fruit, ovules one or more per carpel, fruit of various forms, usually baccate or fleshy aggregates.
Mostly tropical, many genera.

Annona L.

Small trees or shrubs with twigs tending to zig-zag, leaves alternate, simple, entire; flowers with two series of 3 perianth segments, these leathery, green; fruit an aggregate of fleshy carpels; seeds large, hard, embedded in the fleshy, often edible pulp.
A tropical genus, several species widely planted for their sweet edible fruits, two planted in Maupiti.

Annona muricata L. n.v. corasol; soursop

Planted for its large green softly spiny fruit.
Fosberg, sight record.

Annona reticulata L. n.v. bullock's heart

Planted for its almost smooth edible fruit.
Fosberg, sight record.

LAURACEAE

Mostly woody plants (a Maupiti one herbaceous), leaves simple, ex-stipulate (rarely none); flowers bisexual, with 1 or more series of perianth parts, receptacle enlarged; anthers opening by terminal pores with lids; carpel usually one, with one ovule; fruit a drupe or berry, often partly enclosed in a receptacular cupule.
A large mostly tropical family with many ill-distinguished genera, one native, one introduced in Maupiti.

Cassytha L.

Leafless string-like parasites, yellow or orange to green, with haustoria that penetrate plants that they touch; short few-flowered spikes of white flowers, drupaceous fruits.
One pantropical species, common especially in coastal lowlands, other more local species, the widespread one in Maupiti.

Cassytha filiformis L.

Tangled string-like vine, orange to green, smooth to slightly striate, branching with 1-several tiny scale-like reduced leaves at ramifications, stems coiling around stems of other plant's, where touching another stem, of a host plant or its own, producing disk-like swellings or haustoria which adhere and draw water and nutrients from the host; producing short flowering spikes 1_3 cm long, up to 8_10 sessile white flowers, rhachis minutely sparsely pilosulous, flowers subtended by 3 minute scale-like bracts closely appressed, alternating with them 3 closely appressed disk-like scale-like margined sepals, inserted on edge of perigynous disk, alternating with 3 convex triangular-ovate petals, white, valvate, tardily opening, showing at least 2 series, of 3 each, convex stamens, style very short, blunt-pointed, protruding from top of the flask-shaped ovary, this partly embedded in the bottom of the perigynous disk; fruit globose, enveloped in somewhat adherent accrescent disk, and crowned by persistent sepals, petals stamen and style, disk becoming fleshy, white, the whole drupe-like.
Pantropical and very common in most places, parasitic on many hosts, including grasses and sedges, seen even to parasitize itself; abundant at lower elevations and especially on motus in Maupiti.
Fosberg 64885 (US)

Persea Mill.

A tropical American (or in a broader sense, pantropical) genus of trees, flowers grayish, small, in panicles; fruit a one-seeded berry. Many species, one or two and their cultivars are the avocados of tropical horticulture.

Persea americana Mill. n.v. avocado
Persea gratissima Gaertn. f.

Planted as a food tree, not common on Maupiti, but occasionally seems to be spontaneous.
Fosberg, sight record.

HERNANDIACEAE

A few genera of tropical trees, much like Lauraceae, fruit a nut surrounded by, but free from, a fleshy envelope with an opening at the summit.

Hernandia L.

Trees and shrubs with large entire petiolate entire leaves, cymose inflorescences of grayish small flowers, balloon-like fleshy fruits with a hard globose nut with a single seed.
Pantropical with several Pacific islands species, one a strand plant in Maupiti.

Hernandia sonora L. n.v. tonina

Tree, reaching a large size, light colored bark, glabrous except inflorescence, branchlets rather thick; leaves alternate, blades ovate-orbicular, acute, subcoriacious, glossy above, palmately veined, petiole somewhat shorter than blade, attached peltately, about 2 cm in from base, stiff; inflorescence an axillary cyme, fruiting inflorescence somewhat shorter than subtending leaf, rhachis straight, stiff, with a few or several stiff fruiting branches persisting near apex, each bearing a large shortly pedicillate white or rose-purple fruit consisting of a large globose thin fleshy crisp envelope with a small circular aperture, inside of which is the fruit proper, a black subglobose stipitate nut with 3 vertical flutings, a circular constriction near apex, and a single large seed.
Fosberg 64808 (US), 64919 (US).

CAPPARIDACEAE

Trees, shrubs and herbs, many tropical and in arid areas, often ill-smelling; leaves alternate, entire or pseudo-compound, usually palmately so; flowers usually 5-parted, with calyx, corolla, of free petals, few to many stamens, pistil with ovary (and later fruit) usually on a conspicuous gynophore; fruit many-seeded.
Rather few widespread genera.

Cleome L.

Ill-scented herbs with petiolate palmately parted leaves, minute sometimes spinose stipules, racemes of flowers; capsular fruits.

Cleome viscosa L.

A yellow-flowered ill-scented herb.
Pantropical weed of disturbed and cultivated ground, one small plant found on Maupiti in edge of watermelon field on Motu Taina.
Fosberg 64857 (US).

BRASSICACEAE (CRUCIFERAE)

Large family of mostly north-temperate herbs, rarely suffrutescent, leaves simple but often variously dissected or lobed; flowers in racemes, petals 4, stamens 6, pistil with 2-celled ovary, fruit a capsule or indehiscent, seeds one or more in a cell.

Very few representatives in Pacific islands, mostly exotic.

Cardamine L.

Small annual or perennial herbs with pinnately lobed leaves, white flowers, linear capsules (siliques) elastically dehiscent, scattering the very small seeds, leaving the septum persistent.

One poorly understood native Pacific island species, others reported.

Cardamine sarmentosa Sol. ex Forst. f.

Widely distributed Polynesian herb, apparently very rare in Maupiti, one tiny plant found, possibly introduced on Maupiti.

Fosberg 64906 (US).

Lepidium L.

Herbs with entire, toothed or pinnately divided leaves; racemes of small flowers, fruit a short 2-celled capsule (silicle) compressed contrary to the septum, dehiscing septicidally, one compressed seed in each locule.

Many north temperate, especially arid zone species, a few Pacific islands species, one widely distributed strand plant, found on motus of Maupiti.

Lepidium bidentatum Montin

Erect herb, when old slightly woody below, glabrous; leaves alternate, rather crowded toward tips of stems, spatulate to oblanceolate, usually toothed toward apex, attenuate to base to a short petiole, midrib obscure, especially above; racemes terminal, becoming elongate, flowering distally mature fruit at base, petals 4, white, 1.5–2 mm long, stamens 6, ovary flat, stigma subsessile; fruit on pedicels about 6 mm long divergent-ascending, silicle elliptic, convex dorsally, about 5 mm long, slightly emarginate with persistent very short style in notch, septum transverse vertical, persistent hyaline after dehiscence; seed cream-buff color, narrowly obovate, flattened slightly asymmetric, 2.5 mm long.

Found on strands and close to shores throughout Polynesia, in Maupiti near seaward sides of motus.

Fosberg 64748 (US)

FABACEAE (LEGUMINOSAE)

Enormously diverse very large cosmopolitan family, with alternate usually stipulate usually compound leaves, radially or mostly bilaterally symmetric flowers, these 5-merous, usually racemose or paniculate, with usually one carpel; fruit various, but usually a single-celled capsule or legume, with one row of seeds.

Abrus Adans.

Vines with simply pinnate leaves, small racemes of flowers; dehiscent pods of subglobose seeds.

One pantropical species found at rather low elevations, especially coastal.

Abrus precatorius L.

Slender tough woody vine; leaves alternate, simply pinnate; flowers in an interrupted secund raceme; pods straight, more or less terete, readily dehiscent, seed bright scarlet or vermillion with one end black.

The seeds are considered very poisonous, used for making seed jewelry and decorating other handcraft. Quite common on Maupiti on lower slopes and occasional on motus.

Albizia Durazz.
(Often spelled, incorrectly, Albizzia)

Trees or large shrubs, with evenly bipinnately compound leaves; heads or more rarely short spikes of radially symmetrical flowers, 5 sepals and petals, many stamens; fruit usually a thin flat dehiscent pod with transverse seeds.

Many species, mostly tropical, two introduced and naturalized in Maupiti.

Albizia falcataria (L.) Fosb.
Albizia falcata (L.) Baker

A tall tree with white smooth bark; bipinnate leaves with many small leaflets, short spikes of flowers with white filiments; fruit a flat papery pod.

A fast-growing tree, native of Moluccas and New Guinea, widely planted by foresters, on Maupiti much planted at low elevations and becoming naturalized.

Fosberg 64825 (US), 64919 (US); Gillette 3 (US).

Albizia lebbeck (L.) Benth. n.v. woman's tongue tree
(often incorrectly spelled lebbek)

A spreading tree with large pale flat pods.

A few trees seen on a low ridge on S.W. angle of island in scrub forest. Widely introduced on islands as a source of charcoal.

Bauhinia L.

Small trees, shrubs or vines; leaves alternate, characteristically emarginate, bifid, or even divided into two leaflets; flowers showy, axillary, conspicuously bilaterally symmetrical, sepals united at base or most of the way up, forming a cup, vexillum folded inside the wings, stamens variously reduced in numbers, pod strong, elastically dehiscent, the valves coiling.

A large tropical genus, many species, planted as ornamental, two unidentified species, at least, in Maupiti.

Bauhinia sp.

Shrub, laeves round, emarginate.
Shrub growing along trail, sterile.
Morris 19 (US).

Bauhinia sp.

Small tree, leaves tapering somewhat toward the divided apex.
Planted ornamental, only seen sterile.
Fosberg, sight record.

Caesalpinia L.
Poinciana L.

Trees, shrubs, and vines, unarmed to very prickly; leaves evenly bipinnately compound; flowers in racemes, often very showy, sepals variously united, petals clawed, vexillum often narrower, often differing in color from other petals, stamens often strongly exserted; fruit diverse, usually with large seeds.

Caesalpinia pulcherrima (L.) Sw. n.v. pride of Barbados
Poinciana pulcherrima L.

Planted ornamental on Maupiti, both the scarlet and orange flowered forms present.
Fosberg 64881 (US), 64882 (US).

Canavalia Adans.

Creepers or climbers, rarely erect herbs, leaves trifoliolate, flowers showy, on pedunculate axillary racemes, vexillum usually erect or somewhat reflexed; fruit a tough tardily dehiscent pod with a keel on each side close to the main suture.

A pantropical genus, common in coastal lowlands, one species on Maupiti.

Canavalia cathartica Thouars n.v. pipi ta'ero

Extensive herbaceous twining vine, glabrous; leaves alternate, trifoliolate lateral leaflets oval, outer half somewhat broader, on short petiolules, these thick curved, several mm long, middle leaflet suborbicular, jointed to a prolongation of petiole up to 4 cm long, all leaflets very shortly acuminate, bases rounded, petiole 2/3 as long as terminal leaflet; flowering spikes a few cm long, elongating, on long peduncles, flowers a few mm apart, sessile on small pulvini, buds reflexed; flowers papilionaceous, calyx cylindric about 12 mm long, 4–5 mm wide, irregularly several-toothed; corolla bright rose pink, vexillum broadly obovate, emarginate, reflexed, wings held closely around the somewhat curved keel; legumes oblong, somewhat inflated, with 2 keels several mm from ventral suture, several seeded, seed brown, 15×8 mm, scarcely compressed, hilum linear, about 1 cm long.

Pantropical strand and coastal species; on Maupiti local in edges of woods and thickets.
Raynal 17832 (p. 1337); Fosberg 64765 (US).

Cassia L.
Senna Mill.

An enormous genus, containing trees, shrubs and herbs, divided by some botanists into several or many smaller genera, here maintained in a broad sense; leaves simply even-pinnate; flowers showy, usually yellow, in racemes, sometimes conspicuously bracteate, vexillum in bud inside wings; stamens 10, or variously reduced, free; pods terete or variously compressed, angled, or winged, dehiscent or indehiscent.

Cassia alata L. n.v. candle-bush

Planted ornamental, not seen to set fruit in Maupiti.
Fosberg 64977 (US)

Centrosema DC.

Twiners, leaves trifoliolate with persistent stipules, stipellate, middle leaflet on a petiolule; flowers with a large showy vexillum; pods narrow, linear, prominently beaked, sutures thick, septate between seeds.

An American genus, several weedy species naturalized in Pacific islands.

Centrosema plumieri (Turp. ex Pers.) Benth.

A common twiner in many Pacific islands, introduced from America; very common at low elevations in Maupiti.

Fosberg 64764 (US).

Delonix Raf.

A small genus of trees related to Caesalpinia, native to Madagascar, one species is planted throughout the tropics as a gorgeous ornamental.

Delonix regia (Boj.) Raf.

Fosberg, doubtful sight record.

Derris Lour.

Large vines, extensively climbing over other vegetation; leaves pinnately compound, usually with large leaflets; flowers in racemes, but introduced species seldom seen flowering; pods compressed, often with a narrow wing on upper suture.

Several species widely introduced in Polynesia for rotenone production, one common in Maupiti.

Derris malaccensis (Roxb.) Benth.

Derris elliptica sensu auct. non (Roxb.) Benth.

An extensive liana abundant at middle elevations, perhaps introduced into Maupiti as a source of rotenone, seen only sterile.

Fosberg 64761 (US); Morris 28 (US).

Desmodium Desv.

Herbs, rarely shrubs, erect or rarely twiners; leaves trifoliolate, occasionally at least partly unifoliolate, stipules striate; flowers racemose or racemes axillary and much reduced or spikes; fruit jointed, separating into loments, these frequently covered with short hooked hairs.

A large genus, tropical and temperate; two weedy species known from Maupiti.

Desmodium heterocarpon var. strigosum v. Meeuwen — n.v. piripiri 'aratita

Not seen during 1985 survey, probably introduced in Maupiti.

Raynal 17860 (p. 1338)

Desmodium scorpinus (Sw.) Desv.

Trailing twining slender herbaceous vine, seen only on south part of Motu Auira, fruit very narrow.

Fosberg 64846 (US).

Erythrina L.

Trees or shrubs often prickly, tending to be deciduous in dry periods; leaves pinnately trifoliolate; flowers borne on usually terminal racemes, corolla often red or orange, vexillum often conspicuous, wings greatly exceeding keel, stamens 10; fruit dehiscent or indehiscent; seeds often red.

A large tropical genus, some species planted as ornamentals, one endemic Society Islands species almost extinct, one species very widespread in Indo-Pacific, including Maupiti.

Erythrina variegata var. orientalis (L.) Merr. — n.v. coral tree

Erythrina indica Lam.

Large spreading tree, trunk and branches sparsely beset with sharp, broad-based prickles, leaves large, trifoliolate, leaflets as broad as or broader than long, in dry periods dropping during flowering periods; flowers in stiff racemes, these and calyces densely brown-pubescent, petals red, vexillum exceeding wings; pods terete, torulose, tardily dehiscent or breaking irregularly; seeds bean-like, bright red.

A widely distributed tree, sometimes planted as an ornamental, naturalized or perhaps native in many Pacific islands, common in forest on lower slopes in Maupiti.

Fosberg 64796 (US), 64797 (US); Gillette 12 (US).

Indigofera L.

A very large tropical genus of shrubs and herbs; leaves odd-pinnately compound, trifoliolate or unifoliolate, stipules very small; flowers in axillary racemes or spikes, small, usually red or salmon color, pods various, usually terete, curved, beaked.

One weedy species introduced in Maupiti.

Indigofera spicata Forssk.

Widespread weed and green-manure plant, locally naturalized and abundant on roadsides in Maupiti.

Fosberg 64952 (US)

Inga Mill.

Large genus of tropical American trees, leaves pinnately compound, rhachis often notably winged; flowers radially symmetrical, with long conspicuous white stamens; seeds with a white sweet aril, often eaten, at least by children.

One species introduced and locally naturalized in Polynesia.

Inga ynga (Vellozo) J. W. Moore
Inga edulis Mart.

Widely introduced in Polynesia, native of tropical America; in Maupiti probably planted as ornamental.

Fosberg 64941 (US).

Inocarpus Forst.

A small genus of Malayo-Polynesian trees, rather anomalous in the family, leaves simple or unifoliolate; flowers small, not zygomorphic; fruit a 1-seeded fleshy indehiscent pod.

One species widespread in Polynesia, an important food plant in Society Islands.

Inocarpus fagifer (Park.) Fosb. n.v. mape; Tahitian chestnut
Aniotum fagiferum Parkinson

A large tree often with conspicuous thin plank-buttresses; leaves large, thin, oblong; flowers in short axillary spikdes, petals small, whitish equal, fruit somewhat oblique, about 71.5 cm or smaller, fleshy, drupe-like, with one large edible seed.

A very common and important tree ranging from Malaya to Tahiti; frequent on the wooded slopes and coastal lowland forests and thickets on Maupiti, prized for its seeds, eaten roasted.

Fosberg 64822 (US), 64952 (US).

Leucaena Benth.

Medium sized genus of mostly tropical American shrubs and small trees, one indigenous Pacific island species, one pantropical weed shrub or tree, leaves bipinnately compound, leaflets small, flowers radially symmetric, in heads, white; pods flat, thin, seeds transverse.

Leucaena leucocephala (Lam.) de Wit
Leucaena glauca sensu auct. non (L.) Benth.

Pantropical weedy shrub or tree, on Maupiti a localized dense stand of large plants on Motu Taina, a few plants seen on coastal strip of main island.
Fosberg 64858 (US).

Macroptilium (Benth.) Urban
Phaseolus L. (pro minor parte)

A small tropical American genus, segregated from Phaseolus, herbaceous, erect or twining, flowers crowded at summit of stout erect peduncles; vexillum large, keel and wings somewhat twisted; pods narrowly linear, dehiscent, valves tightly twisting.

Macroptilium atropurpureum (DC.) Urban

Widespread weed, in Maupiti twining in lowland thickets.
Fosberg 64939 (US), 64956 (US); Gillette 2 (US).

Mimosa L. s. str.

A tropical American genus of prickly shrubs, lianas, and herbs with bipinnate, sometimes sensitive leaves, heads of tiny flowers, and pods that separate at maturity into 1-seeded segments, leaving intact the two sutures connected at the distal end.

Mimosa pudica L. n.v. sensitive plant

A well-known pan-tropical weedy plant, famous for its leaves, which collapse when touched; common in coastal lowlands and slopes on Maupiti.
Fosberg 64764 (US)

Phaseolus L.

A genus of twiners and creepers with trifoliolate leaves, racemes of twisted flowers and pod-like fruits. The beans, of which there are numerous cultivated varieties.

Phaseolus adenanthus G.F.W Mey.

A slender herbaceous twiner found occasionally on Maupiti.
Fosberg 64770 (US), 64795 (US); Morris 20 (US).

Sophora L.

Many species of shrubs and trees; leaves even-pinnate, racemes of yellow or rarely white irregular flowers, 10 stamens with free filiments, pods tending to be moniliform.

Sophora tomentosa L.

A diffusely branching spreading shrub, reach 2–3 m in height; leaves gray-green, tomentose, even pinnate with pairs of broad, rounded-obovate leaflets; spike-like racemes of yellow flowers.

Pantropical coastal shrub, occasional on strand and lowlands, especially on motus on Maupiti.

Fosberg 64811 (US).

Tamarindus L.

A genus of one species of tree, widespread in the tropics through the agency of man.

Tamarindus indica L.

A tree, prized for its pods with edible acid pulp; widely planted and naturalized in the tropics, presumably native in Indian Ocean region, in Maupiti very sparingly naturalized in lowland thickets.
Fosberg 64923 (US).

Tephrosia Pers.

Tropical and warm temperate herbs with odd pinnate leaves, racemose flowers and pods. Some species are important sources of rotenone, others are planted for green-manure.

Tephrosia piscatoria Pers. n.v. hora tahiti
Tephrosia purpurea (L.) Pers.

A dwarf shrub, stiffly branched; leaves small, with several to 5 or 6 pairs of small obovate leaflets, white or pinkish flowers, compressed falcate pods about 40×3–4 mm.
Sometimes not distinguished from the south Asian T. purpurea. This very sparse, small, depauperate form is found in oceanic Polynesia, was used by Polynesians as a fish poison. Noticed on Maupiti on high rocky ridges.
Fosberg 64775 (US)

Vigna Savi

Herbs with trifoliate leaves, irregular flowers, cylindric pods.

Vigna marina (Burm.) Merr.

Extensively creeping and climbing herb, branching and tangled, young growth twining, almost glabrous sparse retrorse appressed hairs on youngest growth, stems prostrate to ascending, leaves and peduncles curved at base, erect or ascending; petioles stiff, angular, leaflets 3, broadly ovate, obtuse, lateral petiolules very short, thick, central one 1.5–2 cm long, stipels stiff orbicular, thick-scale-like, racemes very short, few-flowered, on peduncles slightly shorter than leaves, pedicels 2–3 mm long, bracts so small as to be almost not evident; calyx campanulate, lower 2 teeth low triangular, upper very obtuse, ciliate; vexillum showy, yellow, broader than high, cordate, emarginate, wings obliquely ovate, obtuse, sessile, keel-petals separate in basal portion, united distally, strongly curved vertically, not at all twisted; pods cylindric, strongly deflexed, curved outward, very shortly beaked, not or very slightly constricted between the 4–6 seeds.
A widespread Indo-Pacific strand species, probably contributing importantly to the fertility of the very poor calcareous soils of coral motus and atolls. Nodules have been observed on the roots of these plants in other areas. Very abundant on Maupiti, even climbing into trees.
Fosberg 64787 (US), 64809 (US); Gillette 4 (US).

OXALIDACEAE

A cosmopolitan family, mostly herbs, a few small shrubs, 2 species of trees, leaves compound, flowers 5 merous, radially symmetric, fruit a capsule or berry.

Oxalis L.

Mostly herbs with trifoliate leaves, solitary or cymose flowers, fruit a thin-walled capsule with many seeds.

Oxalis corniculata L.

A small herb with leaves palmately compound with 3 obcordate leaflets on a slender stalk; flower with 5 yellow petals; fruit a prismatic beaked thin-walled capsule.

Cosmopolitan weed, on Maupiti one colony seen in grassy opening on coastal flat.

Fosberg 64951 (US).

RUTACEAE

Aromatic trees and shrubs, rarely herbs; leaves and other parts with gland-dots, mostly compound or unifolioate leaves, flowers radially symmetric, fruit usually baccate or capsular.

Citrus L.

Small trees and shrubs, often thorny, leaves mostly unifoliate, rarely trifoliate; flowers very fragrant, waxy, white; fruit a berry with a prominently glandular rind.

Citrus aurantiifolia (Christm.) Swingle n.v. lime

Planted for its fruit.

Fosberg, sight record.

Citrus maxima (Burm.) Merr. n.v. Pomelo; Pampelmousse

Citrus decumana L.

Not seen bearing fruit, but fruit served on table in hotel, probably grown on the island.

Fosberg, sight record.

Citrus sp.

One plant found in coastal thicket. Appears to be a very large leafed plant related to C. aurantiifolia (the lime), but specimen is sterile.

Fosberg 64976 (US).

SURIANACEAE

Family of one genus, characters of Suriana maritima.

Suriana L.

Genus of one pantropical species; characters of S. maritima.

Suriana maritima L.

Large bushy shrub with dark brown branches, pubescent to glandular pubescent in all parts, much branched; leaves alternate, oblancolate to spatulate, only the midrib visible, apex rounded to acutish, base cuneate narrowed to almost no petiole; small panicles of flowers axillary, open, bracteate, bracts small, lanceolate, subtending each branch and pedicel, branching only once or twice, branches racemose, pedicels less than 1 cm; calyx 5-parted almost to base, segments narrowly ovate, slightly acuminate; petals yellow, falling early in day; suborbicular, stamens 10, unequal, pilose toward base, ovaries and styles 5, styles from inner bases of separate carpels, 3–5 pubescent hard druplets or nutlets developing, these obovoid to globose, style persistent at inner base of nutlet.

A pantropical strand plant, usually growing on coral sand, frequent on lagoon beaches. The rosette-like cluster of leaves at the branch tips spread in sunlight, close up at night or during stormy weather.
Fosberg 64835 (US).

EUPHORBIACEAE

Habit various, leaves simple or compound, stipules present, rarely interpetiolar; flowers in terminal or axillary cymes, or solitary or fasciculate in leaf axils or in reduced cup-shaped inflorescences called cyathea, flowers mostly without petals, but frequently with petaloid bracts or appendages, ovary 3- or more-celled, placentation axile; one or two ovules in a locule, fruit a capsule or rarely a drupe or berry.

Acalypha L.

Shrubs or herbs, with alternate, often ovate and serrate leaves, these often with 3 veins from base; stipules paired at base of petiole; staminate flowers in catkins, very small, pistillate reduced to simple pistil with capillary branched styles, 3-loculate ovaries, 1 ovule in a locule, subtended by an often reduced bract, on a catkin-like spike or in an axillary head or fascicle.

Acalypha amentacea Roxb. cv.

Planted ornamental.
Fosberg 64936 (US).

Acalypha amentacea ssp. wilkesiana (M.-A.) Fosb.

Planted ornamental, noted for its multicolored, mostly red leaves.
Fosberg, sight record.

Aleurites Forst.

Tree with large alternate usually lobed leaves; panicles of white flowers; fruit a 1–3 loculate drupe, mesocarp firm, dehiscent, releasing hard nut-like endocarp with a single large oily seed.

Aleurites moluccana (L.) Willd. n.v. tutui or tuitui; Candlenut

A spreading tree, becoming large under favorable conditions, leaves light green, large, with 3 or 5 lobes usually only shallowly divided; panicles of white flowers; fruit a round or twinned drupe the fleshy mesocarp drying and peeling off, leaving a hard ribbed endocarp, whitish but when rubbed or waterworn becoming very black, kernel very oily, cathartic when eaten, formerly strung and burned as a candle in certain Pacific Island cultures.

Very rare on Maupiti, probably brought from Malay Archipelago to Polynesia by aborigines, seeds used as a condiment and as equivalent of a candle. Nuts often cast up on beaches.
Gillette 9 (US).

Breynia Forst.

Shrubs with distichous simple entire leaves, small axillary flowers lacking petals; fruit a somewhat fleshy capsule.

Breynia disticha Forst.

Planted ornamental, only the variegated form seen.
Fosberg 64877 (US).

Codiaeum Juss.

Shrubs with alternate subcoriaceous leaves, unisexual flowers, staminate with many crowded stamens; pistillate reduced to trilocular ovules with 3 divergent styles.

Codiaeum variegatum (L.) Bl.

One of the commonest tropical ornamental shrubs, a myriad of strikingly different leaf forms; very common in Maupiti.

Fosberg, sight record.

Euphorbia L. subg. Chamaesyce

Herbs and shrubs, lactiferous, main axis aborted at second node, second axis with opposite, distichous leaves and interpetiolar stipules, each internode ending in a branch, and distal ones in a cyathium or an inflorescence of cyathia, each cyathium containing several or more stamens and a single pistillate flower reduced to a single stipitate trilocular ovary with 3 style branches; fruit a 3-celled capsule with 3 seeds, edge of cyathium with 4–5 discoid glands, each of these with or without a petaloid appendage.

Pantropical, many species, one native in Maupiti, several introduced weeds.

Ephorbia atoto Forst. f. sensu lato n.v. aihere tapau

Slender shrub to 1 m tall, stems rather brittle, lactiferous, somewhat nodose, branching distichous, forming a broad V; leaves opposite, distichous, oblong-oval, rounded at apex, wooly above near base and petiole, base sub-cordate, under-surface white, leaves close-set, slightly imbricate, petioles 2–3 mm, stipules rounded-ovate, basal part fleshy, distal part thin, reddish, margin nearly black, minutely ciliolate; cymes terminal, sessile, a pedicellate cyathium in each fork, 2 ascending branches twice branched, branchlets ending in triads; cyathium cup-shaped, with 4 green circular marginal glands, each with a broad white reniform marginal appendage, stamens many, ovary exserted on a recurved stipe, triangular broadly ovoid, with very small erect stigmas, tips slightly spreading; stipes erect after capsules have dehisced. No ripe capsules available.

Local form of a widespread Polynesian species complex, with a close relative distributed as far west at least as tropical Australia. Taxonomy of group very uncertain.

Raynal 17838 (p 1338); Fosberg 64747 (US), 64989 (US), 64849 (US), 64856 (US), 64865 (US).

Euphorbia hirta L.

A common pantropical herbaceous weed, with erect pubescent stems, arching at tips, dense clusters of tiny cyathia with white petaloid gland appendages; very common in open or disturbed areas on Maupiti.

Fosberg & Sachet 64965 (US).

Euphorbia prostrata Ait.

A very widespread small weed, very prostrate, dark purplish green, stems pubescent on upper side, capsules hairy on angles only; occasional in open bare ground on Maupiti.

Fosberg 64864 (US).

Euphorbia rubicunda Bl.

Euphorbia thymifolia sensu auct. non L.

A widespread tropical weed, prostrate, dull greenish, capsules not well-exserted from cyathia, capsule pubescent all over; common in the village in Maupiti.

Fosberg 64901 (US).

Glochidion Forst.
Phyllanthus L. pro parte excl. type.

Shrubs or small trees, branches not dimorphic, leaves alternate, not notably distichous, bases usually with 2 sides unequal, vein network often prominent, petioles short, flowers very small, unisexual, solitary or in very small fascicles, mostly distal, styles erect, coherent, short, or stigmas sessile; ovary more than 3-loculed, fruit discoid, dehiscing loculicidally, with 2 seeds surrounded by a red arils in each cell. Many species, Indo-Pacific, difficult to classify.

Glochidion sp.

Shrub 1–3 m tall, irregularly branched, leaves alternate, simple, apex acuminate, base usually unequal on two sides, pinnately veined, veins, inconspicuous, petiole short, 2–3 mm, thick, curved; staminate flowers yellow, axillary on filiform curved pedicels, mostly 1 at an axil, segments obovate, about 1.5 mm long; pistillate flowers 1-several at an axil, on filiform Pedicels unequal, 3–5 mm long, straight, perianth segments 6, 1 mm or less long, closely appressed to an erect style 1.5–2.5 mm long, obscurely 6-lobed at summit; fruit thick disk-shaped, 10×3.5 m, obscurely 6-lobed, 6-loculed, the persistent narrowly cylindric style in a depression at center of top of fruit; seeds 2 in a cell, rounded but contiguous sides of a pair flattened, covered by a bright red aril, one or more seeds in a capsule may be abortive.
Endemic (?) to Maupiti, on flat ground in interior of motus and on high peaks and ridges.
Fosberg 64755 (US), 64891 (US); Fosberg & Sachet 64962 (US).

Jatropha L.

Thick-stemmed herbs or shrubs, latex clear, not milky, leaves entire to extremely divided, palmately veined; flowers in cymes, red or green, corolla present, fruit a capsule.

Jatropha integerrima var. hastata (Jacq.) Fosb.

Commonly planted ornamental, shrub with slightly hastate leaves, flowers unisexual, monoecious, corolla bright crimson, showy, of relatively recent introduction in the Pacific, said to be a native of Cuba.
Fosberg 64876 (US).

Manihot L.

Shrubs or small trees, leaves long-petiolate, tending to be palmately lobed or compound, flowers unisexual, monecious, in upper cymes, fruit a capsule.

Manihot esculenta Crantz n.v. cassava; tapioca
Manihot utilissima Pohl

Erect shrub with knobby stems, large elongate tuberous roots which are very starchy; leaves petiolate, deeply palmately parted, flowers rather small, capsules 3-celled.
Widely planted shrub, native of Brazil, its roots yielding tapioca starch, very abundantly planted in Maupiti, especially in the coastal strip and on lower slopes.
Morris 29 (US).

Pedilanthus Neck. ex Poit.

Fleshy-stemmed shrubs, leaves distichous, flowers in slipper-shaped cyathia; ovary 3-celled; fruit a capsule.

Pedilanthus tithymaloides (L.) Poit. n.v. shoe flower

Planted ornamental, stems dark green or variegated, leaves likewise, cyathium narrow, pointed, red.

Fosberg 64934 (US).

Phyllanthus L.

Herbs, shrubs or small trees, branches strongly dimorphic; leaves distichous, in some species closing at night; flowers small, borne in axils of leaves on slender horizontal branches; fruit a loculicidal, usually triloculate capsule, this rarely fleshy and indehiscent; 2 seeds in each locule.

Phyllanthus amarus Sch. n.v. moemoe

Slender erect herb, main stem simple or sparsely branching, fertile branchlets numerous, with pinnately arranged small leaves, these oblong, rounded at both ends, subsessile, stipules triangular acuminate; flowers minute hanging beneath leaves, a single pistillate at each proximal node, at distal nodes a pistillate and a staminate; pistillate with 5 tepals, ovary 3-celled, with 3 sessile stigmas, capsule depressed globose, 3-celled.

A widespread tropical weed in disturbed places; in Maupiti common around dwellings and in village.

Raynal 17867 (p. 1338); Fosberg 64804 (US), 64909 (US); Fosberg & Sachet 64964 (US).

Phyllanthus virgatus Forst. f. n.v. moemoe

Small rather stiff herb, single-stemmed (single-branched) or few-branched from base, leaves distichously arranged, ovate or ovate-lanceolate, flowers small, in leaf axils, fruit a 3-celled capsule.

Found once on Maupiti but not seen on 1985 survey.

Raynal 17841 (p. 1338).

ANACARDIACEAE

Habit various, sap tending to be resinous and with terebinthine odor, irritating to skin in some people, some species very much so; leaves simple or usually pinnately compound or trifoliate, flowers small, usually somewhat zygomorphic, often paniculate, ovary superior, fruit commonly drupaceous.

Mangifera L.

Large trees, sap resinous, causing dermatitus in some people, leaves simple; flowers small, in large clusters, very irregular; ovary unilocular, fruit a drupe with fibrous endocarp.

Mangifera indica L. n.v. mango

Widely distributed tree, planted for its fruit and naturalized on most tropical islands, one of most abundant trees on Maupiti; dominant in ravines and on lowest slopes.

Morris 12 (US).

Spondias L.

A small genus of trees found in tropics of both hemispheres, leaves pinnate, flowers paniculate, fruit fleshy, edible.

Spondias dulcis Parkinson n.v. vi; hog plum

Large openly branched tree, semi-deciduous or deciduous in dry season; leaves alternate, large,

odd-pinnately compound, leaflets thin, 7–9; flowers small, fruit a large globose drupe with a large corky stone, flesh sweet, edible.

Society Island tree, bearing an edible fruit, introduced elsewhere; occasional on coastal strip of Maupiti, possibly planted.

Fosberg, sight record.

CELASTRACEAE

Shrubs, trees or vines, leaves simple, alternate or opposite, tending to be crenate-serrate margined, stipules none; flowers in cymes, with a prominent disk, 4 or 5 merous, stamens alternating with petals; ovary superior; fruit a capsule or a drupe, seed often arillate.

Celastrus L.

Shrubs, often spiny, leaves alternate, flowers small, fruit a capsule, sometimes somewhat fleshy, aril surrounding lower part of seed.

Celastrus crenatus Forst. f. (This species is to be transferred to the genus Maytenus Mol., but the name has not been published yet.)

Shrub or small tree, branchlets slender, leaves small, ovate to elliptic, apex somewhat acuminate, margins crenate.

Widely distributed on high islands of Polynesia, very rare in upper forests or thickets of Maupiti.

Morris 25 (US).

RHAMNACEAE

Trees, shrubs or vines; leaves simple, alternate or opposite, flowers small, stamens opposite petals and often enclosed by them, ovary superior or inferior; fruit often an indehiscent capsule or drupe.

Colubrina Rich. ex Brongn.

Small trees with hard wood, or semi-scrambling shrubs; leaves alternate, rarely opposite, flowers small, greenish, in few-flowered clusters; fruit a semi-inferior capsule, tardily dehiscent or indehiscent. A pan-tropical genus of rather few species, one pantropical.

Colubrina asiatica (L.) Brongn. n.v.ami

Scrambling, semi-climbing shrub, glabrous, branching, stems round; leaves alternate, sub-orbicular cordate, acuminate, margins crenate-serrate, petiole up to 1 cm; flowers axillary, 1–2 at an axil, green, 5-parted, small, stamens opposite petals; fruit globose or slightly depressed-globose, calyx disk adnate to base of fruit, capsule 3-celled, slightly depressed on top, tardily dehiscent or indehiscent; seeds 1 in a cell; hard, brown, 2 plane faces at an angle, one convex face.

Pantropical, mostly in semi-dry or moist areas; in Maupiti seen on mountain ridge and on coastal strip.

Raynal 17837 (p. 1337); Fosberg 64774 (US), 64979 (US).

TILIACEAE

Habit various, creeping herbs to trees; leaves simple alternate, tending to be palmately lobed and veined, or cordate, usually pubescent, often stellately so, flowers with 5 petals, usually many stamens, ovary superior, entire or 4-lobed, fruit frequently indehiscent.

Grewia L.

Trees with trinerved serrate leaves, fruit deeply 4-lobed.
Pantropical genus, many species.

Grewia crenata (Forst.) Schinz & Guill. n.v. haupa

Small tree; leaves medium small, ovate, somewhat acuminate at apex, truncate to subcordate at base, trinerved, margins somewhat serrate, flowers rather small, greenish to white, stamens many, fruit hairy, 4-lobed, deeply divided, seed 1 in a cell.

Found once in Maupiti but not seen on this 1985 survey.
Raynal 17844 (p. 1338)

Triumfetta L.

Herbs or somewhat shrubby, leaves usually with cordate base, lobed or not, even on same plant; flowers axillary in small clusters or on spikes, calyx deeply lobed, fruit a globose spiny burr, indehiscent, spines often barbed or hooked.

Triumfetta procumbens Forst. f.

Prostrate, elongate trailing herb, occasionally with erect branches, vegetative parts, calyx and fruit pubescent, the hairs mostly branched or stellate; branches and leaves alternate, ovate or orbicular to trilobed, thick, apex obtuse or rounded, base cordate, margin crenate, venation palmate, 5–7 principal veins, network fine, petiole equal to or shorter than blade; stipules subulate to linear; flowers in leaf-opposed triads, appearing terminal at first, calyx cup-shaped at base, deeply 5-lobed, lobes narrowly spatulate; petals yellow, 5, narrowly elliptic to obovate, just shorter than sepals, apex somewhat erose; stamens many, erect, somewhat unequal; fruit a globose burr, spines many, not very stiff or sharp.

A widely distributed Pacific strand species, in Maupiti common on motus.
Fosberg 64863 (US).

Triumfetta rhomboidea Jacq. n.v. toteto

Erect herb with cordate leaves, usually somewhat shallowly lobed or angled, pubescent, inflorescence of several arching spikes, flowers yellow, petals separate, stamens many; fruit globose, densely woolly, with short weak hooked spines.

Pantropical weed, the form in Society Islands has very elongate inflorescence branches, very abundant on Maupiti, especially in lowlands. The small burrs stick to clothing causing great annoyance.

Raynal 17827 (p. 1337); Fosberg 64829 (US), 64925 (US).

MALVACEAE

Plants of various habit, herbs, shrubs, or trees, with a strong tendency to stellate pubescence, to strong bast fibers in stems, and to mucilage production in tissues; leaves simple, alternate, often cordate and palmately veined, stipules present and separate; flowers variously arranged, basically axillary, pentamerous, involucrate or not, calyx united, usually 5-lobed, petals 5, fused at base with filiments which are united, at least in lower portion, into a staminal tube with free portions of filaments bearing anthers separating from upper part of tube; pistil 1, with ovary 5- or more loculed, style enclosed by staminal tube, separation where exserted into 5 or more branches, or these fused, with stigmas free or fused; fruit a capsule, berry or schizocarp, locules with one or several seeds.

Gossypium L.

Coarse herbs, sometimes suffrutescent or lower stem woody, all parts dark punctate with glands

producing gossypol, a poisonous yellow substance; leaves petiolate, often 3–5 lobed, palmately veined; flowers on axillary 1-flowered peduncles, with an involucre of 3 expanded, fan-shaped usually lacinate bracts, calyx sheathing base of flower, not strongly lobed, flower large, not opening widely, petals erect; ovary 3-loculed, locules with few or several ovules; capsule hard, ovoid, beaked, glandular, loculicidal, opening wide exposing seeds ordinarily covered by masses of 2 types of fiber, called cotton.

Gossypium barbadense L. n.v. cotton

A tall suffrutescent herb with 3–5 lobed leaves, the lobes ovate with sides of lobes curved, stipules, flowers subtended by an involucre of 3 erect laciniate bracts, corolla bright yellow, 5–6 cm long, capsule ovoid, acuminate, punctate, hard, 3-valved, dehiscent, seeds several in a cell, densely white-woolly.

Planted for fiber, or possibly persisting from such planting.

Fosberg 64937 (US).

Gossypium hirsutum var. taitense (Parl.) Roberty

Shrub to 2.5 m tall, most parts punctate with black dots, glabrous; leaves alternate, on long stiff slender petiole, blades trilobed, apices acuminate, base deeply cordate, basal sinus mostly closed, basal lobes touching or overlapping, the three distal lobes broadly ovate, their sides nearly straight or somewhat concave; stipules immediately caducous, represented by a scar [minute hairy lanceolate appendage observed at one node-a stipule?] flowers borne singly on long stiff axillary peduncles, at summit of peduncle a reduced leaf, then a very short internode, then the involucre of three large cordate deeply laciniate bracts, flower sessile, calyx bowl-shaped, subtruncate, only very obscurely trilobed; corolla about 4 cm long, cream color, fading reddish, base of five petals united; staminal column short, about 1 cm, style about 2 cm long, stigma clavate; fruit (boll) about 1.5 cm long, beak slender, 3 mm long, seeds about 7, fiber pale brown, about 1 cm long.

Found on a high rocky ridge in scrub vegetation.

Fosberg 64781 (US).

Hibiscus L.

A large genus of herbs, shrubs and trees, leaves variously shaped; stipules small, or large and enclosing terminal bud; flowers on axillary jointed peduncles, involucre a whorl of 5 or more usually narrow, lanceolate bracts, calyx sheathing, with free lobes, or teeth, petals often very showy, style branches 5, stigmas globose, pubescent; fruit a 5-loculed loculicidally dehiscent capsule with usually many seeds.

Hibiscus abelmoschus L.
Abelmoschus moschatus Medic.

Erect hirsute herb, leaves variously 3–5 lobed or angled, petiolate, flowers large, to 5 cm acorss, on strong peduncles in upper axils, involucre of 8–10 linear bracts, it and calyx early caducous, petals light yellow with almost black maroon base, capsule fusiform, 5-ribbed, slightly inflated.

Widespread weed, very rare in Maupiti, in weedy coastal strip on rock pile (archaeological).

Fosberg 64954 (US).

Hibiscus manihot L.

Erect glabrous small tree, trunk 4–5 cm diameter, gray-brown, leaf scars conspicuous, erect branches (from cut stem), leaves fasciculate on incipient lateral branchlets on branches; leaves lanceolate, to 2-3 dm long, thin, apex acuminate base truncate-hastate or subhastate, with obscure secondary lobing, main veins palmate from base, venation otherwise pinnate, petiole to 13 cm, fleshy; stipule scars (or rudiments) present but no stipule scars seen; peduncles axillary from uppermost

nodes, stiff, thick, strongly ascending, to 10 cm long, receptacle much enlarged, flowers not available, fruiting calyx of 5 separate ovate acuminate segments about 3 cm long; capsule broadly ovoid, apically 5-sulcate, hirsute especially in sulci, slightly lobed at apex.

A single plant growing at edge of a manihot patch; Vaitia Distr.

Fosberg 64914 (US).

Hibiscus hastatus L.f.

Hibiscus tricuspis Banks ex Cav.

A small tree with spreading branches, leaves rather large, petiolate, variously 3-5 lobed lobes entire or cut; stipules large; flowers in a few-flowered raceme, large to 8-10 cm across, yellow with dark center, petals 4-5 cm long, fused at base with staminal column, flowers and fruits practically identical with those of Hibiscus tiliaceus.

A Society Island species, possibly a form of Hibiscus tiliaceus, but with very different leaves, very rare on coastal strip of Maupiti.

Fosberg 64931 (US).

Hibiscus rosa-sinensis L. n.v. red hibiscus

A showy bright red ornamental hibiscus, present in the Society Islands in pre-European time, one of the species crossed to create many of the many ornamental hybrid cultivars; this or plants very similar to it commonly planted as ornamentals on Maupiti.

Fosberg, sight record.

Hibiscus tiliaceus L. n.v. purau

Pariti tiliacea (L.) St. Hil.

Low tree with short or no trunk, arching or decumbent, frequently tangled branches, with very tough bast fiber, especially in young growth on mature trees; under sides of leaves and stipules densely stellate-tomentose, on juveniles, sprouts, etc. only thinly puberulent; leaves orbicular, slightly acuminate, deeply cordate at base, white beneath, except juvenile, margin entire (serrate in seedlings), venation palmate, 9 veins from base, pinnate above, with ladder-like arrangement between larger veins, network obscure; stipules large, conspicuous, ovate to oblong, extra-petiolar, bases contiguous outside base of petiole; soon caducous; flowers on initially terminal peduncles with a pair of small stipules and a small leaf at summit subtending a thick pedicel, a branch then arising at the node at base of peduncle, opposed to the leaf at that node, this succession repeated resulting in a cymose arrangement of flowers and fruits; flower closely subtended by an involucre of 10 short lanceolate bracts; calyx of 5 ovate-lanceolate acuminate sepals united at base; corolla showy, of 5 broadly obovate yellow petals, dark maroon at base, yellow part fading reddish, base united and adnate to base of staminal column; column about half length of corolla, free filaments and anthers almost the whole length of column, except basal 3 mm; style with exserted part and 5 short stiff erect branches and clavate stigmas velutinous, maroon color, whole flower about 6 cm long; capsule ovoid-subglobose, 2.5 cm long, on recurved pedicel slightly beaked, sericeous, loculicidal with 5 valves; seeds reniform or obliquely reniform, dark brown.

Pantropical strand and lowland plant, stems producing bast fiber useful for cordage, dominant plant on slopes in Maupiti, abundant also in valleys and lowlands.

Hibiscus (Ornamental hybrids)

An enormous series of cultivars of hybrid origin, of variously mixed parentage; one of the most showy groups of tropical ornamentals, planted in most tropical countries, symbolic of tropical color and luxuriance.

Generalized description: Upright shrub; leaves alternate, simple, usually somewhat serrate toward apex, petiolate, generally ovate; stipules linear or lanceolate; flowering peduncles axillary, flowers large with an involucre of a whorl of linear or lanceolate bracts, calyx tubular with 5 lobes; corolla with

5 large showy obovate petals, bases fused and united with bases of stamens which are fused into a filament tube or staminal column, the numerous anthers on free filament-tips at the top of the column; style enclosed in staminal column; the five branches exserted from top, tipped with globose velvety stigmas, fruit a septicidal capsule; seeds usually lacking, if present usually hairy.

Fosberg, sight record.

Malvastrum Gray

Herbs with yellow or orange flowers, a depressed ovary maturing to a schizocarp separating into a number of 1-seeded carpids.

Malvastrum coromandelianum (L.) Garcke

Tough herb, leaves ovate, serrate, bright green, appressed hirsute beneath, flower orange.
Pantropical weed; on Maupiti a weed in cultivated ground and occasional along roadsides.
Fosberg 64805 (US), 64859 (US).

Malvaviscus Fabr.

Shrub with usually red, hibiscus-like flowers that never open widely, often pendent; fruit baccate.

Malvaviscus arboreus Cav.

Common planted ornamental, petals imbricately lobed at base.
Fosberg 64943 (US).

Sida L.

A large genus of herbs or sometimes slightly woody, with usually dentate leaves, flowers small, on simple or jointed pedicels, these in some species numerous above and forming a panicle, lacking an involucre, calyx sometimes somewhat inflated or plicate-keeled, corolla orange, white or maroon; schizocarp of 5 or more carpids, these sometimes strongly 2-toothed or stiff awned, reticulate on sides.

Sida acuta Burm. f.

Herb, leaves usually appearing distichous, green, flowers subsessile.
A pantropical weed, rare in Maupiti, collected in village.
Fosberg 64803 (US).

Sida rhombifolia L.

Pantropical weed, very variable, one form very common in Maupiti, leaves grayish-green, pedicels long, jointed, flower dull orange. Along roadsides and paths, and in disturbed or cultivated ground.
Fosberg 64832 (US).

Thespesia Sol. ex Correa

Small trees with dense dark-reddish wood; leaves strongly cordate, margins entire; flowers solitary on axillary peduncles, involucre of 3 small spirally arranged ovate bracts, buds and immature fruits exuding a yellow latex-like gossypol when cut, flowers showy lemmon yellow, turning dark reddish when old, staminal tube short, style-branches, and stigmas coherent, fruit a depressed globose tough indehiscent capsule, subtended by persistent calyx, seeds several to few in a locule, pubescent.

Thespesia populnea (L.) Sol. ex Correa

Small tree with thickish stiff round, pointed, cordate leaves, flowers about 5 cm long.
Common widespread coastal species pantropically, common along shores on Maupiti.
Fosberg 64815 (US), 64949 (US).

Urena L.

A sprawling, often semi-woody herb with rather small pink to rose-purple flowers. A genus with one or few species, pan-tropical.

Urena lobata L.

Tall sparsely branched suffructescent herb, leaves orbicular to ovate, simple, shallowly or deeply and intricately lobed; flowers pink, in upper axils and on terminal spikes, 5-parted, stamens with filaments fused; fruit 4-lobed, covered by hooked spines.
Pantropical weed, rare on Maupiti, seen only once near village on roadside.
Fosberg, sight record.

CLUSIACEAE (GUTTIFERAE)

Shrub or trees, often large, with opposite, usually leathery or fleshy large opposite leaves, yellow or white latex; stipules lacking; flowers with imbricate perianth, often scarcely differentiated into calyx and corolla; many stamens, one pistil with stigma sessile on ovary, fruit a drupe, berry or capsule, seeds one to several or many.

Calophyllum L.

Trees with large pinnately-parallel veined opposite leaves, lactiferous; flowers in axillary racemes, rather small with imbricate petaloid perianth; many stamens; fruit a drupe with thin flesh, a single large seed enclosed tightly in a hard endocarp.
A pan-tropical genus with rather many species.

Calophyllum inophyllum L.

Large spreading tree, lactiferous, young branches sharply 4-angled, glabrous except pyramidal terminal bud which is closely minutely brown-scurfy; leaves opposite, oblong with rounded apex and base, blade entire, about 20×10 cm, entire, coriaceous, finely pinnately parallel veined, abruptly slightly decurrent into a rather thick petiole about 2 cm long, curved at base; racemes of flowers axillary or leaf-opposed, white, 7–11 or more flowered, sometimes branched, pedicels 1.5–2 cm long, ascending, buds globose, perianth of 6 (or 8) petaloid parts very concave and imbricate, orbicular; stamens numerous, shorter than petals; ovary globose, white, stigma minute, sessile; fruit a globose drupe about 2.5–3.5 cm diameter, mesocarp thin, fibrous, endocarp of a thin bony layer and a spongy layer grown to a hard testa (?) surrounding a globose firm fleshy seed, this completely homogeneous within, yellowish or cream white, embryo not at all evident.
A widely dispersed Indo-Pacific strand and lowland tree, yielding a high-quality wood, useful for carving and construction; on Maupiti common on motus and island shores. Fruit ideally adapted for dispersal by water, the perfectly spherical endocarps common in beach drift, appearing viable even when obviously weathered.

FLACOURTIACEAE

A rather non-descript family of woody plants; leaves simple; stipules lacking; flowers not showy, with 2 whorls of perianth parts; ovary 1-loculed with parietal placentation, fruit various, frequently baccate; seeds usually many.

Xylosma Forst. f.

Shrubs and small trees, leaves with crenate-serrate margins, pistil with a peltate lobed stigma, fruit a berry.

Xylosma suaveolens (Forst.) Forst. f. sensu lato n.v. ? (pine a Tahiti, fide Nadeaud)

Small tree, leaves alternate, ovate to broadly elliptic, petiole short; flowers dioecious, on short axillary racemes, perianth ciliate, staminate with many stamens, pistillate with an ovary with subsessile stigma, berry subglobose, black. Common in eastern Polynesia.

Widespread Polynesian species, rare on Maupiti, found in higher elevation forests.

Raynal 17848 (p. 1338); Morris 18 (US)

CARICACEAE

Thick-stemmed herbaceous or semi-woody plants, lactiferous; with palmately-veined petiolate leaves; no stipules, flowers very diverse, axillary and solitary or paniculate; stamens in two whorls; placentation parietal; fruit fleshy, seeds arillate. Tropical American and African.

Carica L.

Characters of family.

Carica papaya L. n.v. papaya; pawpaw

Thick-stemmed erect, usually unbranched tree with a crown of very large deeply lobed and dissected leaves, flowers polygamo-diecious or polygamous, pistillate large and axillary, staminate and bisexual in axillary panicles.

Universally planted and naturalized in the tropics for its fine edible fruit; common around dwellings in Maupiti.

Fosberg, sight record.

CUCURBITACEAE

Mostly herbaceous tendrilliferous vines, a few erect herbs and woody vines, rarely shrubs, leaves alternate, usually palmately veined and lobed; stipules none; flowers mostly unisexual, pistillate with an inferior ovary, unilocular with parietal plancentation; fruit usually a berry, sometimes dehiscent, seeds 1-many. A large, almost world-wide family.

Citrullus Schrader

Creeper with deeply and sinuously lobed leaves, small yellow-flowers, monoecious usually, and large fruit, center cavity filled with fleshy tissue, with flattened seeds each in a small cavity. A small Old World genus of warm, usually semi-arid regions.

Citrullus lanatus var. caffrorum (Alef.) Fosb. n.v. water-melon; pastecque

Extensively cultivated on motus in Maupiti for its fruit, which is sold in Tahiti.

Fosberg 64851 (US).

THYMELAEACEAE

Woody plants with strong bast fibers; leaves simple, alternate or opposite; flowers racemose, appearing spicate, or in umbells, perianth of one connate series, and tubular with 4–5 lobes, sometimes, an inner reduced whorl, stamens 2, 4–5 or 8–10, inserted on calyx tube; ovary superior, one ovule in a cell; fruit fleshy or dry. A largely tropical and temperate family, one genus common in

Polynesia.

Wikstroemia Endl.

Shrubs or small trees with smooth dark red or red-brown bark, pairs of white lenticels between attachments of petioles; leaves green to more or less yellowish green, opposite; flowers in usually short or capitate, but often elongating spike-like racemes, dioecious, perianth yellow to yellow-green, tubular, 4-lobed, lobes patently spreading; stamens 8; ovary superior, style short or not, fruit a drupe-like 1-seeded berry, said to be toxic.

A genus of a few variable species, or many ill-defined ones, with Indo-Pacific distribution.

Wikstroemia raiatensis J.W. Moore n.v. avao
Wikstroemia foetida sensu auct. plur. non (L.f.) A. Gray

Shrub with usually smooth dark brown or maroon stems, very tough fiber in bark, opposite simple entire green to olive green leaves, stipules none but in their place paired white scars; flowers in very short pendent spikes or heads, perianth of one series, tubular with spreading 4-parted limb, 8 stamens in throat, pistil 1, fruit a soft red ovoid berry with one seed slightly pilosulous at apex.

The name W. foetida has traditionally been used for this extremely variable species, but proves to have been misapplied to it. The above name may be used for it, at least until a critical study of the southern Polynesian species of Wikstroemia has been made.

Found once on Maupiti, not seen on 1985 survey.

Raynal 17849 (p. 1338)

Wilkstroemia sp.

A single small tree of a peculiar Wikstroemia, substerile, much-branched, with almost pendulous branchlets, large elliptic leaves, and capitate, non-elongating inflorescences was found on a ledge near the top of a precipitous slope on the east side of Holuparaoa Ridge, in thick forest. Its habit, leaf size and shape, as well as capitate non-elongating inflorescences distinguish it from the widespread Polynesian species which has been incorrectly known as W. foetida L. f. (see above). Our specimens, lacking flowers or fruits, is scarcely good enough to base a new species on in this difficult genus.

Fosberg 64295 (US, BISH, Papeete)

LYTHRACEAE

Herbs, shrubs or trees, leaves opposite, tending to be distictous, simple; stipules lacking; flowers axillary and solitary, or in terminal spikes; calyx of 4–8 sepals, on a tubular or cup-shaped hypanthium petals free, 4, 6 or 8, or 10, radial or rarely zygomorphic, often clawed, blades thin and delicate; stamens usually twice as many as the petals, rarely fewer, very rarely many, pistil one, ovary usually closely invested by calyx, so as to appear inferior, in some genera partly inferior, 1–6 loculed, several to many ovules per locule, placentation axile, fruit usually capsular.

Pemphis Forst.

A strand genus, found throughout the Indo-Pacific region excepting Hawaii, mainly insular, of two species only. Wood of trunk very dense and hard.

Pemphis acidula Forst.

Erect slender intricately branched shrub or small tree; leaves opposite, small, elliptic, grayish green, sour or astringent when chewed; flowers, six white petals, axillary, heterostylous, calyx united striate; fruit fleshy.

Fosberg 64841 (US).

RHIZOPHORACEAE

A small tropical family of woody plants of diverse habit, leaves opposite, stipules interpetiolar, wrapped around bud, caducous.

Rhizophora L. n.v. mangrove

Trees with prop roots, axillary cymes of 4-parted flowers, petals ciliate, included, caducous; ovary inferior, seed germinating on tree, radical elongating, thick, fleshy, falling from tree and dispersed by floating.

Rhizophora mucronata var. stylosa (Griff.) Schimper

Not known growing on Maupiti, but 5–6 propagules found in beach drift on lagoon side of Motu Auira, several still green and probably viable, probably drifted from Moorea or Tahoa, where introduced.

Fosberg 64815 (US).

LECHYTHIDACEAE

Tree with alternate large leaves; flowers with many stamens, inferior ovary; fruit a woody capsule or a fleshy or fibrous drupe.

Barringtonia Forst.

Tree with ample leaves, stipules none, flowers in elongate spike-like racemes or solitary; petals 4 or more, stamens many, showy, united at base, early caducous; fruit large, with fleshy or fiberous pericarp; a single large seed.

A genus of a few species in Old World Tropics.

Barringtonia asiatica (L.) Kurz n.v. hotu

Large tree, trunk often swollen and distorted at base, at least when old, glabrous, branchlets rather thick; leaves alternate, very large, obovate, rounded at apex, subcordate at base, coriaceous, main veins conspicuous, margins entire, petiole thick short, curved; stipules none; flowers large, calyx persistent, 4-parted, spreading, petals stamens numerous to 5 cm long, coherent at base, falling as a unit; ovary inferior, style exceeding stamens, fruit very large, turbinate, round to usually square in transverse outline at largest part, corky within, with smooth tough exocarp, a single large seed.

The fruit floats and is a common object in beach-drift, often seen germinating near tops of beaches.

An Indo-Pacific strand tree, reaching a large size, in Maupiti occasional individuals or groves at top of and back of beaches, the large round or square fruits common on beaches; seeds said to be poisonous, used to poison fish.

Fosberg 64814 (US).

MYRTACEAE

Trees, shrubs or rarely climbers; very often aromatic; leaves simple, opposite or in a few genera alternate, usually punctate with pellucid oil glands; stipules usually lacking, flowers with inferior ovary, usually with many, often showy stamens; fruit either a fleshy berry or a hard capsule.

Eugenia L.

Shrubs and trees, aromatic; leaves opposite, gland dotted; flowers on axillary pedicels or in axillary cymes, sepals 5, persistent, petals 5, caducous, stamens many, epigynous; fruit fleshy, with one or several large seeds.

Eugenia cuminii (L.) Druce n.v. Java plum
Eugenia jambolana Lam.

A south Asian-Indonesian tree species that has been abundantly naturalized in many Pacific islands. It is common in various places in Maupiti, including locally on the motus. Its small fleshy fruit is edible but astringent.
Fosberg & Sachet 64966 (US).

Eugenia malaccensis L. n.v. mountain apple; Malay apple

Tree reaching large size; leaves opposite, large, oblong to elliptic or ovate, slightly acuminate; inflorescence thyrsoid-paniculate, few-branched, axillary or cauline, flowers large, with many crimson stamens, fruit a berry, to 5 or more cm in diameter, 1-2 large seeds more or less free from the thick sweet aromatic crisp but watery flesh, pale green to reddish when ripe.
Widely distributed in the Pacific and Malesia, producing an edible fruit, on Maupiti occasional on lower slopes and coastal strip. Probably carried about and introduced by Polynesians.
Morris 13 (US); Fosberg, sight record.

Eugenia uniflora L.

Shrub, much branched, leaves opposite, ovate, flowers axillary, white, small, fruit a depressed globose deeply lobed red, turning maroon or black, juicy berry, with persistent round sepals.
Planted food plant, possibly naturalized but rarely seen in Maupiti.
Fosberg 64947 (US).

Psidium L.

Shrubs and trees with smooth bark, flowers white with small sepals; large white petals; fruit fleshy with many small hard seeds embeded in a soft pulp. Of tropical American origin, widely introduced throughout tropics.

Psidium guajava L.

Very widespread shrub or small tree with smooth bronze colored bark, native of tropical America but carried over the tropics for its edible fruit, in Maupiti an important component of montane scrub and forest.
Morris 24 (US).

ONAGRACEAE

Herbs, rarely shrubs or small trees, leaves alternate, simple, stipules none; flowers with inferior ovary, petals 4, stamens 8; ovary usually 4-loculate, ovules and seeds many.

Ludwigia L.

Herbs, terrestrial or aquatic, flowers usually yellow, petals fugaceous; fruit a capsule with spreading persistent sepals, seeds small, many.

Ludwigia octovalvis (Jacq.) Raven

Erect herb, becoming slightly suffrutescent, to 1.5–2 m tall, branched, stems reddish brown, slightly angled, young stems slightly pilose; leaves alternate, lanceolate, narrowly acute at apex and base, pinnate venation prominent on under surface, subsessile or very short-petioled; flowers in upper axils on short pedicels; ovary inferior; sepals 4, ovate-acuminate, spreading, about 1 cm long; petals 4,

bright yellow, obovate orbicular, 1.5 cm long, slightly emarginate, falling very easily by mid-day; fruit clavate, 3.5 – 4 cm long, sepals tardily caducous, fruit walls disintegrating, leaving persistent fibers; seeds numerous, about 0.6 mm wide, rounded, pale straw-color, smooth.

A pan-tropical plant of marshy places, rice and taro fields, probably spread accidentally by Polynesians and Micronesians; in Maupiti found in taro patches and wet spots in interior of motus.

Fosberg 64756 (US); Fosberg & Sachet 64963 (US).

ARALIACEAE

Mostly trees, oily or resinous-aromatic; leaves usually compound, petiole-bases expanded, inflorescences usually compound umbels; flowers radially symetrically, perianth in 2 series, outer very small, usually 5-parted; stamens the same number or more; ovary usually inferior, locules usually 5 ovules 1 in a locule; fruit a drupe.

Pantropical, rare in Temperate Zone.

Polyscias Forst.

Mostly shrubs, leaves pinnately compound or unifoliolate; inflorescence a racemose compound umbel; fruit usually 2-locular. An Indo-Pacific genus with several cultivated ornamental species.

Polyscias filicifolia (Moore) Bailey

Planted ornamental; leaves once pinnate with long shallowly lobed leaflets.

Fosberg, sight record.

Polyscias fruticosa (L.) Harms

Planted ornamental, leaves decompound.

Fosberg, sight record.

Polyscias guilfoylei (Cogn. ex March) Merr.

Planted ornamental, leaves pinnately compound, leaflets few, broadly elliptic, usually with white remotely serrate margins.

Fosberg, sight record.

Polyscias tricochleata (Miq.) Fosb.

Planted ornamental, leaves trifoliolate, leaflets round, crenate-margined.

Fosberg, sight record.

UMBELLIFERAE

Oily aromatic herbs, rarely woody, with simple or usually compound leaves, with expanded bases, flowers in umbels, calyx reduced, petals 5; stamens 5, ovary 2-celled; fruit with longitudinal oil-ducts, a schizocarp splitting into 2 mericarps.

Centella L.

Creepers with rhizomes superficial or buried, leaves reniform, shallowly dentate, flowers and fruit axillary.

Centella asiatica (L.) Urb.

Creeping herb rooting at nodes, leaves orbicular-reniform, flowers inconspicuous, axillary.

Widespread in Old World tropics, with a close relative in the New World, not certain how far east it is native in the Pacific, generally considered introduced; rare in lowlands of Maupiti in disturbed places.

Fosberg 64791 (US).

PLUMBAGINACEAE

Shrubs or herbs, leaves in rosettes or alternate, simple; flowers spicate or paniculate, 5-merous, ovary 1-loculed, with one basal ovule.

Plumbago L.

Scrambling herb or slender shrub, flowers in terminal spikes, calyx cylindric, strongly stipitate glandular, corolla salverform, with 5 obovate patent lobes; fruit a capsule with one seed.

Plumbago zeylanica L. n.v. ava turatura

Scrambling herb with striate, slightly zigzag stems; alternate broadly ovate leaves acute to usually obtuse but slightly acuminate apex, obtuse base decurrent on petiole, blade thin, to 6×4 (–5) cm, glabrous and very minutely pale punctate above, thinly scurfy beneath, petiole to 3 cm long, margined, expanded to form rounded stipule-like auricles and slightly sheathing at base; racemes 1–2 or several terminally, pedicels very short, 1 mm or less, subtended by an oblong green or brownish bract and two bracteoles, flowers rather crowded on a rhachis up to 13 cm long, peduncle 1 or less cm, lower part of rhachis clothed only with dried persistent bracts and bracteoles; calyces spreading from rhachis, cylindric, strongly ribbed and sulcate, deeply toothed at summit, the whole conspicuously clothed with erect viscous-glandular hairs; corolla white, glabrous, about 1.5 cm long, salverform with 5 ovate lobes and slightly funnelform throat, marcescent; fruit a single-celled capsule, closely invested by persistent calyx, with a single seed, basally attached.

A wide-spread Indo-Pacific species, ideally equipped for bird-dispersal, having reached as far east as the Marquesas and Henderson Island. In Maupiti it has been found on the tops of high peaks and on the coastal flats.

Raynal 17842 (p. 1338); Fosberg 64773 (US), 64942 (US).

OLEACEAE

Trees, shrubs and climbers, leaves simple or pinnately compound, opposite or subopposite; stipules none; flowers various, corolla gamopetalous or none; stamens 2 or rarely 4; pistil 1, fruit a drupe, capsule, or samara.

Jasminum L.

A shrub, scrambler or vine, leaves opposite or rarely alternate, simple, trifoliate or pinnate; flowers in cymes or panicles, rarely solitary, axillary, calyx 4-many-lobed; corolla gamopetalous, radially symmetric or somewhat zygomorphic, somewhat or quite salverform, usually very fragrant; fruit a pair of small drupes.

Jasminum didymum Forst. f. n.v. ti'ati'a mou'a/mau'a

A tough slender liana, stems twining or scrambling; leaves opposite, trifoliolate, leaflets broadly ovate, somewhat acuminate, inflorescence thyrsoid-cymose, open, flowers small, white, fragrant, 4-merous; fruit a pair of globose black drupes.

Widespread southern Polynesia to Australia; occasional on wooded slopes and ridges in Maupiti, locally tangled in thickets.

Raynal 17846 (p. 1338), Fosberg 64771 (US).

Jasminum grandiflorum L.

Ordinarily a planted ornamental, but found apparently naturalized at one place on the NW shore of Maupiti, flowering but not seen setting fruit.
Fosberg 64916 (US).

Jasminum multiflorum (Burm. f.) Andr. n.v. star jasmine
Jasminum pubescens Willd.

Planted ornamental; shrubby with white star-like fragrant flowers.
Fosberg, sight record.

GENTIANACEAE

Herbs, more rarely shrubs or trees, glabrous; leaves simple, opposite; stipules none or two small lobes, or a low ridge or ring; flowers solitary or in cymes, terminal, calyx gamosepalous; corolla gamopetalus, 5-merous, anthers in sinuses, or in throat, ovary superior, placentation parietal; fruit a capsule or a berry; seeds many.

Fagraea Thunb.

Trees or shrubs; leaves coriaceous, mostly rather long; flowers solitary or in few-flowered cymes; calyx short, corolla large white, waxy, turning yellowish, very fragrant; stamens and style included; fruit a large globose, ovoid, or ellipsoid, orange berry, with many seeds embedded in pulp. (This genus is usually placed in the family Loganiaceae.)

Fagraea berteriana A. Gray ex Bentham

Handsome tree, leaves large, opposite, obovate, coriaceous; flowers in few-flowered cymes, calyx small, corolla large, tubular-salverform, very fragrant, white turning cream-yellow with age, fruit a large orange berry with many seeds.

A widespread tree in the Pacific Islands, with many local varieties, its flowers prized for their odor; occasional in lowlands on Maupiti, mostly probably planted.
Fosberg, sight record.

APOCYNACEAE

Herbs, shrubs, vines and trees, often lactiferous; leaves opposite, whorled, a rarely crowded and spirally arranged, simple, entire; stipules none; flowers variously disposed, often in irregular cymes; calyx usually divided almost or quite to base; corolla gamopetalous usually contorted in bud, sometimes with scales in throat; anthers sessile in a close ring in tube or throat; pistil of 2 or rarely more separate carpels, united above in a single style with an apparatus subtending the stigma called a clavuncle; fruit a follicle or drupe, usually in pairs; seeds usually flattened, sometimes comose.

Catharanthus G. Don

Herbs or suffrutescent; simple or branched at or near base, stems leafy, flowers appearing terminal but in uppermost axils, corolla salverform; fruit linear in pairs in upper axils. A small genus principally from Madagascar, one species pantropical, planted and naturalized.

Catharanthus roseus (L.) G. Don

Suffrutescent herb, many stems from base, sparingly branched above, most parts minutely puberulent, stems green or red, internodes short; leaves opposite, simple elliptic to oblong, pinnately veined, 5-7 nerves on a side, apex obtuse to rounded, minutely mucronulate, petiole short, 2-4 mm;

flowers solitary, axillary, subsessile; sepals 5, lanceolate subulate; corolla salver-form, white to rose purple, tube slender, abruptly enlarged, then contracted near summit, lobes spreading, very broadly obovate, mucronate, mucro to one side of center, throat almost closed, slightly elevated and closely ciliate, slightly bearded within, lobes twisted to left in bud, anthers included, linear-oblong, style filiform, stigma (clavuncle) cylindric with 2 abrupt constrictions, just below anthers; fruit of two free linear erect carpels, shorter than leaves, apices bluntly acute.

Native of Madagascar, now widely planted and naturalized in the tropics and warm-temperate areas; medicinal properties being intensively investigated.

Fosberg 64837 (US), 64860 (US).

Nerium L.

Shrubs with watery sap, opposite or whorled narrow leathery leaves, and corymbose cymes of showy flowers, corolla with scales in throat; anthers with plumose appendages; fruit a slender elongate capsule. All parts of the plant are very poisonous.

Nerium oleander L. n.v. oleander

Planted ornamental, with pink or white flowers; highly poisonous.

Fosberg, sight record.

Plumeria L.

Thick-stemmed shrub or small trees, very lactiferous; semi-deciduous; leaves crowded, spirally arranged; rounded cymes of large, very fragrant flowers.

Native of tropical America, planted throughout the tropics.

Plumeria obtusa L. n.v. Singapore; plumeria

Tree with cuneate obtuse dark green venulose leaves; white flowers.

Planted ornamental.

Fosberg, sight record.

Plumeria rubra L. n.v. frangipani; plumeria

Planted ornamental, thick-stemmed tree with narrow elleptic strongly acuminate leaves, flower color extremely variable; with clusters of variously colored very fragrant flowers.

Fosberg 64883 (US).

Tabernaemontana L.

Shrubs and trees with salverform flowers, usually white, and fruit consisting of paired dry or fleshy ovoid follicles. Considered in a broad sense found throughout the tropics. Often segregated into many small ill-distinguished genera.

Tabernaemontana divaricata (L.) R. Br. n.v. false gardenia; faux tiare

Tabernaemontane coronaria (Jacq.) Willd.

Ervatamia coronaria (Jacq.) Stapf

Slender dark green shrub; flowers salverform, white, single or double, in slender few flowered cymes. Planted ornamental, originating in India.

Fosberg, sight record.

CONVOLVULACEAE

Herbs or somewhat shrubby, usually somewhat lactiferous, mostly twining vines, very rarely trees; leaves alternate, usually more or less cordate; flowers mostly large and showy, on unbranched or branched axillary peduncles or cymes, calyx of 5 separate overlapping sepals; corolla usually trumpet shaped or campanulate, with 5 broad veins, stamens few, attached above base of corolla; fruit a capsule, rarely a fibrous berry.

Ipomoea L.

Vines, very rarely erect shrubs; flowers large, showy tubular, campanulate or funnelform; anthers straight, pollen grains spiny under high magnification, style filiform, stigma capitate, with 2 or 3 fused heads, fruit a 4-celled capsule.

Ipomoea batatas (L.) Poir. n.v. sweet potato

Planted for its edible tuberous roots, a pre-European plant in Polynesia, doubtless of American origin.

Morris 34 (US); Fosberg 64852 (US); Fosberg & Sachet 64967 (US).

Ipomoea fistulosa Mart. ex Choisy

Planted ornamental, beginning to become naturalized, native of South America, erect habit unusual in Convolvulaceae; flowers pink.

Fosberg 64944 (US).

Ipomoea littoralis Bl.

Ipomoea denticulata Choisy

Ipomoea gracilis sensu auct. non R. Br.

A slender twiner with alternate sagittate to ovate-cordate thin leaves; rose-purple corolla, dark in throat.

A pantropical small morning glory, occasional at all elevations on Maupiti.

Morris 5 (US); Fosberg 64779 (US), 64957 (US).

Ipomoea macrantha R. & S. moon-flower

Ipomoea tuba (Schlecht.) G. Don

A large herbaceous vine occurring pantropically in strand and coastal situations, occasional on and behind beach ridges on Maupiti; flowers large, white.

Fosberg 64843 (US), 64853 (US).

Merremia Dennst. ex Hall. f.

Differs from Ipomoea in more clearly campanulate corollas, coiled anthers, smooth pollen grains.

Merremia peltata (L.) Merr.

A very widespread Pacific liana, common locally in slope and coastal forests of Maupiti; flowers large and showy, white.

Gillette 7 (US); Fosberg 64918 (US).

BORAGINACEAE

Herbs, shrubs and trees, rarely climbers, frequently rough pubescent or hispid; leaves simple, alternate; stipules none, inflorescence usually cymose, often scorpioid; calyx of 5 separate or connate sepals, corolla usually at least slightly zygomorphic, often approaching actinomorphic, stamens 5,

inserted on corolla-tube, pistil 1, ovary superior, bilocular or falsely quadrilocular, style gynobasic or terminal, often forked; fruit a drupe or of 4 nutlets, these may be immersed in aerogenous tissue.

Cordia L.

Trees or shrubs, leaves tending to be rough, petiolate; inflorescence a loose cyme or in some species a spike-like cyme; few to many flowered; flowers more or less showy; calyx gamosepalous, style branched, with 4 stigmas; fruit a drupe.

Cordia subcordata Lam. n.v. tou

Small to medium well-formed tree with a hard dark and light banded wood; leaves alternate, ovate to broadly elliptic, usually slightly rough on the upper surface, veins prominent, 4–6 on a side; flowers in small open few-flowered axillary cymes, calyx cylindric, unequally 3–4 toothed; corolla funnelform, bright orange, lobes 5, very thin, spreading to recurved, margins crispate, throat somewhat plicate within, stamens, 6–8 included in throat, style 2-branched, each branch with 2 divergent flattened fleshy stigmas, these branches and stigmas exserted, fruit a hard drupe enclosed in the enlarged calyx, drying and becoming hard, bony.

An Indo-Pacific strand and lowland species, prized for its wood; in Maupiti found on beach ridges, especially on motus.

Fosberg 64980 (US), 64875 (US).

Tournefortia L.

Shrubs or rarely small trees, more rarely twiners; inflorescence a usually branched scorpoid cyme; flowers small, style terminal on an unlobed ovary.

Tournefortia argentea L.f.

Shrub or small to medium-size tree with rounded umbrella-shaped crown, branching alternate, branchlets thickish, ending in crowded clusters of obovate to elliptic fleshy leaves on short thick petioles, stems and leaves thinly silky-hairy, giving a somewhat frosty gray-green appearance; inflorescences cymose, terminal on branchlets, subtended at base by two or more leafy branchlets, peduncle simple or forking once at an acute angle, then repeatedly alternately branching, main rhachis with up to 12 or more branches, each forking repeatedly, branchlets ending in a scorpioid spike of ultimately many sessile flowers; calyx with 5 closely appressed obtuse lobes; corolla subrotate, the 5 orbicular white lobes spreading to recurved; 5 short stamens included; ovary ovoid with an apical disk bearing 2 erect white fleshy stigmas; fruit globose, small pea-size, drupaceous, with 2 (or 4) irregular shaped stones, flesh maturing to a dry aerogenous floating tissue.

A widely distributed pioneer strand plant, ranging throughout the Indo-Pacific area, from Africa to Ducie Island, north to the Marianas and Ryukyu Islands excluding Hawaii, but introduced there. Its floating fruits provide a very effective means of dispersal. In Maupiti it is very common on the motus, especially at the top of and just back of the beaches, and on beaches also on the main island.

Fosberg 64975A (US).

VERBENACEAE

Habit various, usually but not always woody, often aromatic when broken; leaves opposite, usually simple, rarely palmately compound or trifoliolate; stipules lacking; inflorescence various, racemose, corymbose, or more rarely spicate or cymose; calyx gamopetalous; corolla usually at least somewhat zygomorphic, 5- rarely more, or 4-lobed, stamens the same number as the corolla lobes, but one commonly reduced to a staminode; ovary superior, of 2 or 4 carpels, cells the same number as carpels or twice as many; fruit a drupe or berry, rarely of four nutlets or a capsule.

Premna L.

Small trees or shrubs, aromatic, rarely spiny; inflorescence cymose; flowers small somewhat zygomorphic; fruit a small berry, with 4 seeds.

Premna serratifolia L. sensu lato n.v. avaro
Premna obtusifolia R. Br.

Small tree or shrub, bark light colored, branchlets often dark with white lenticels; leaves opposite, simple, broadly ovate to broadly oblong, apex obtuse to acuminate, base obtuse to subcordate, petiolate, inflorescence a terminal corymbiform cymose panicle, flat to rarely somewhat rounded on top, 5-20 cm across or more, flowers with united but irregularly 2–5 lobed calyx, corolla pale green to whitish, bilabiate, stamens exserted, fruit a small pea-like black berry with 4 seeds.

Widespread, extremely variable Indo-Pacific species, usually in strand and lowland situations, but only seen very rarely at higher elevations on Maupiti.

Raynal 17843 (p. 1338); Fosberg 64776 (US).

LAMIACEAE (LABIATAE)

Herbs, rarely shrubs, usually aromatic, with square stems and opposite simple leaves; flowers usually in verticels or heads, calyces gamosepalous, corolla gamopetalous and usually conspicuously zygomorphic; stamens ordinarily 2 or 4, in pairs, pistil one, ovary superior, usually 4-lobed, ovules 4, style gynobasic, fruit usually of 4 nutlets, these rarely fleshy, one-seeded.

A large cosmopolitan family with some economic or ornamental members.

Leucas R. Br.

Small herbs, odor weak or none, inflorescence racemose, corolla tubular, not strongly zygomorphic but limb bilabiate, lower lip larger, style-branches 2, very unequal; nutlets triquetrous.

Leucas decemdentata Sm. n.v. niu

Weak herb, leaves opposite, serrate, inflorescence a terminal raceme, subverticillate, flowers white, tubular, bilabiate.

A widespread small herb in the south Pacific, very rare at upper elevations on Maupiti.

Raynal 17835 (p. 1337); Morris 6 (US).

Ocimum L.

Strongly aromatic herbs or somewhat woody shrubs; flowers racemose, in 6-flowered verticels, calyx bilabiate, deflexed in fruit, corolla bilabiate, upper lip 4-lobed, lower lip entire, 4 stamens in 2 pairs; style branches 2; fruit of 4 nutlets. A pantropical genus of a few species, one O. basilicum, widely used for flavoring food, incense, etc.

Ocimum basilicum L. n.v. basil; sweet basil

Planted cooking herb, very pleasantly aromatic; leaves almost entire.

Fosberg 64928 (US).

Ocimum gratissimum L. n.v. miri tahiti (basilic de Tahiti)

Shrubby, leaves broader and bases more abruptly contracted than in O. suave. The Raynal specimen should be reexamined.

Raynal 17824 (p. 1337).

Ocimum suave Willd.

A widely distributed strongly aromatic shrubby plant of tropical American origin; common locally at lower elevations on Maupiti, sometimes united with 0. gratissimum L., leaves notably serrate.
Fosberg 64762 (US).

SOLANACEAE

Habit various, ours herbaceous; leaves alternate, simple entire to dissected; stipules none; flowers usually in axillary cymes or rarely a terminal cluster; flowers usually 5-merous, calyx usually 5-lobed, corolla gamopetalous, often rotate, actinomorphic or somewhat zygomorphic, stamens alternating with corolla lobes; pistil 1, ovary superior, placentation axile, ovules many; fruit a berry or capsule.

Nicotiana L.

Erect herbs; cymes terminal, corymbiform or elongate; flowers tubular, funnelform or salverform; fruit a capsule, seeds many, minute.

Nicotiana tabacum L. n.v. ava'ava tahiti tobacco

Found once on Maupiti, possibly planted, but not seen on 1985 survey; of American origin.
Raynal 17829 (p. 1337).

Solanum L.

Herbs, shrubs, or vines, often spiny; cymes axillary or super-axillary; corolla usually rotate stamens connivent; fruit a berry. The tomatoes are by many botanist placed in a separate genus Lycopersicum; but there seems little reason for this.

Solanum lycopersicum L. n.v. tomato

Much branched glandular herb; leaves pinnately parted; flowers yellow; fruit a juicy berry, seed pubescent but surrounded by pulp.
Food plant, planted or spontaneous.
Fosberg 64867 (US).

SCROPHULARIACEAE

Mostly herbs, a few shrubs, a few herbaceous twiners, 1 genus of trees is usually placed here; leaves simple, opposite or rarely whorled, in a few genera "alternate"; flowers mostly bisexual, racemose, spicate, paniculate or solitary, racemes terminal or axillary; calyx of connate or free sepals; corolla tubular to rotate, very zygomorphic to almost actinomorphic, stamens 5, 1 usually reduced to a staminode or even absent, pistil 1, of 2 corpels, ovary superior, ovules usually many; fruit ordinarily a capsule with many small seeds. A fairly large family, mainly temperate, montane in the tropics.

Angelonia HBK.

Herbs with opposite oblong to lanceolate or narrowly elliptic leaves, stipules none; flowers axillary, solitary or in pairs, or forming bracteate terminal racemes by reduction of leaves; corolla tubular, zygomorphic, showy, stamens and pistil included; fruit a capsule. Several species cultivated as ornamentals.

Angelonia angustifolia Benth.

Planted ornamental; flowers solitary, pedicellate, axillary, corolla usually purple (or white).

Fosberg 64933 (US).

BIGNONACEAE

Mostly trees and lianas; leaves usually opposite or whorled, usually compound, simple in several genera, in vines frequently one or more leaflets modified into climbing organs-tendrils or hooks; stipules none; flowers usually cymose, often paniculate, almost always zygomorphic, tubular or elongate-campanulate, 5-lobed, often bilabiate with lower lip trilobate, stamens 5 but with 1 or rarely 3 modified into staminodes; pistil 2-carpelate, ovary superior, 2-loculate or rarely 1-loculate, ovules many; stigma 2-lobed; fruit usually an elongate dehiscent capsule, in a few genera indehiscent; seeds often on a septum which loosens on dehiscence, often winged and imbricate.

A large mainly tropical family many genera with showy flowers, some cultivated as ornamentals.

Crescentia L.

Irregularly branched shrubby small tree; leaves simple or compound; alternate or fasciculate; flowers with large irregular tubular corolla; fruit a large globose indehiscent hard-shelled berry with large seeds embedded in pulp.

Crescentia cujete L. n.v. calabash tree

Leaves fasciculate simple, spatulate, flowers pale green; fruit large, globose, the shell dried and used as a receptacle or calabash. Planted ornamental.

Fosberg 64932 (US).

Tecoma Juss.

Small tree with pinnate leaves, bright yellow flowers in showy clusters.

Tecoma stans (L.) Juss. ex HBK.

Pantropical ornamental, readily becoming naturalized, apparently very rarely established in Maupiti.

Morris 33 (US).

ACANTHACEAE

Herbs, shrubs or vines, stems often nodose, sometimes geniculate, sometimes spiny; leaves opposite, simple; stipules none; inflorescence usually cymose, or flowers solitary, racemose or spicate, often conspicuously bracteate; flowers with deeply lobed calyx, corolla zygomorphic, bilabiate; stamens usually 2 or 4, inserted on corolla; pistil 1, bicarpellate, ovary superior, 2-celled, ovules few, placentation axile; fruit usually a capsule, mostly elastically dehiscent, seeds 2 or usually 4 or more, often on curved stiff structures called retinacula, unique to this family. A large mainly tropical family, including many tropical ornamentals.

Asystasia Bl.

Herbs with broadly ovate leaves, flowers in a monochasial cyme; capsule 4 seeded.

Asystasia gangetica (L.) Anders.
Asystasia coromandeliana Nees

Planted ornamental climbing herb, flowers showy, variously colored, a pale yellow form seen on Maupiti.

Fosberg 64911 (US).

Barleria L.

Shrubs and herbs, leaves opposite; flowers in terminal bracteate spikes, these often spiny, calyx 4-lobed, 2 lobes large, 2 small, corolla showy, with 5 subequal lobes, stamens 4, in two pairs; fruit a capsule; seeds with bygrosscopic hairs.

Barleria cristata L.

Shrub to 1 m tall, flower spikes very leafy, elongate; flowers with 2 calyx lobes enlarged, ovate, scarious, veiny, margins spinulose-ciliate, other two linear; corolla to 5 cm long, tubular-campanulate, lobes spreading, rounded.
Planted ornamental.
Fosberg, sight record.

Justicia L.

Large pantropical genus, one species naturalized in Maupete.

Justicia betonica L.

Erect herb, spikes with large imbricate white bracts with green reticulate venation.
Widespread weed, in Maupiti seen only very locally on dry rocky slope above road in village.
Fosberg 64940 (US).

Thunbergia L.

Mostly vines, one or more species erect shrubs, flowers very showy, with large spathe-like calyx.

Thunbergia fragrans Roxb.

Twining vine, leaves opposite, triangular-ovate, flowers showy, corolla with a slender tube and broad white limb.
A widely naturalized rather ornamental species, perhaps of southeast Asian or Indonesian origin, locally established on coastal strip on Maupiti.
Fosberg 64902 (US).

RUBIACEAE

Habit various; leaves opposite or occasionally whorled, especially in temperate herbaceous genera, simple, almost always entire; stipules mostly interpetiolar; inflorescence usually cymose or thyrsoid, rarely spicate or flowers solitary; hypanthium fused to and including ovary, "ovary inferior", flowers 3–5, or more merous; calyx usually lobed or toothed, corolla gamopetalous, tubular, funnelform, salverform or rotate, stamens same number as corolla lobes and alternate with them, usually inserted in throat or tube, rarely basal; ovary usually 2-, rarely 1- or more-celled; fruit a capsule, a drupe or berry, rarely a compound drupe or a schizocarp; seeds 1-few or many in a cell, endosperm usually present.

Coffea L.

Shrubs and small trees, branches of 2 sorts, ascending vegetative ones, and slender harizontal flowering branches with leaves appearing distichous; flowers axillary, corolla white, salverform, anthers exserted, style with stigma tardily well-exserted; fruit fleshy with 2 large seeds; each in a thin endocarp, with testa one cell in thickness.

Coffea arabica L. n.v. coffee; cafe

Cultivated throughout the tropics, naturalized on many Pacific islands; planted and naturalized on wooded lower slopes in Maupiti.

Gillette 10 (US); Fosberg 64881 (US).

Gardenia Ellis

Shrubs and small trees, buds tending to be gummy, flowers solitary, axillary or terminal, calyx lobes often with vertical flat appendages, corolla salverform, very fragrant, fruit fleshy, placentae perietal in a unilocular fruit, in which the seeds are embedded in the fleshy placentae.

An Old-World genus with several important ornamental species.

Gardenia taitensis DC. n.v. Tiare Tahiti; Tahitian Gardenia

Glabrous shrub or rarely small tree with round stems, short inter-nodes: leaves broadly obovate or elliptic, glossy bright green, obtuse, 6-8 veins on a side, very short petiole; stipules sheathing, obtuse, embedded in gum in bud, lobes obtuse, splitting at maturity, deciduous with leaves; flowering pedicels terminal, about 1.5 cm long, subtended by two branchlets; hypanthium tricarinate, with 3 oblong-ovate erect appendages perpendicular to floral axis; calyx obscure or lacking; corolla salverform, tube greenish, about 2.5 cm long, slightly dilated to summit, lobes 7, broadly lanceolate, asymmetric, obtuse, white, very fragrant; anthers linear, partly exserted; stigma clavate, with 3 spiral keels, partly exserted; plant not known to set fruit in Society Islands.

Native of Melanesia, of aboriginal introduction and a favorite cultivated ornamental, prized for its fragrant flowers in the Society Islands, including Maupiti.

Fosberg 64783 (US).

Guettarda L.

This genus is typified by G. speciosa, described below. This does not much resemble the New-World species which are included, perhaps incorrectly, in the same genus.

Guettarda speciosa L.

Small tree with well-formed round crown, subglabrous to pubescent, stems slightly 4-sided when young, speckled with pale brown lenticels; leaves opposite, broadly oblong to usually slightly broadly obovate or ovate, apex obtuse, slightly acuminate, base cordate or subcordate, veins prominent beneath, slightly impressed above, 9–12 on a side, connected by prominently scalariform venation, network very fine, of several orders of scalariform network; stipules oblong, as broad or broader than high, apex strongly acuminate, acumen recurved, early caducous; cymes in one or both axils at a node, strong peduncles curving upward, twice branched at summit, a sessile flower in each forking, each ultimate branch scorpioid with 2 rows of sessile buds, flowering from base, cymes when young notably bracteate, bracts lanceolate, caducous; calyx tubular, slightly lobed or subtruncate, 2–3 mm long, caducous, corolla salverform, tube 2–3 cm long, lobes 6–7, imbricate in bud, 6–7, oblong to obovate, spreading, the whole corolla tomentulose, flowers of 2 types, short-styled, with style about 2/3 length of corolla tube, stamens at mouth of corolla with tips exserted, long-styled with style equalling or exceeding corolla tube, stigma exserted, corollas opening in night, falling about mid-morning when hit by sun; fruit a depressed globose drupe, to 2 cm wide, with white flesh, broad calyx ring on flat summit, flesh weathering or eaten by crabs after falling to ground, leaving a fibrous coat, a number of seeds embedded in stone.

An Indo-Pacific strand species, ranging from Africa to eastern Polynesia, north to Marianas, absent from Hawaii, found in upland in Marianas and some other islands, planted as an ornamental at least in Ceylon; apparently spread by its floating fruits.

Fosberg 64812 (US), 64833 (US).

Morinda L.

This is a pantropical genus of trees, shrubs and lianas. It is especially characterized by its fused ovaries, forming a fleshy multiple with corollas protruding from the mass; this, enlarged at maturity forming syncarpic fruit. Two species occur in the Society Islands, one of which is found in Maupiti.

Morinda citrifolia L. n.v. nono

Large shrub or small tree, vegetative parts glabrous, stems square with blunt angles, 5 – 12 mm thick; leaves opposite, large, to 25 or more cm long, 10 – 12 cm wide, ovate to elliptic, apex acute to obtuse, abruptly short acuminate, base cuneate contracted to a short, 1 – 2 cm, thick petiole, blade firm, glossy, (5-) 6 – 8 prominent veins on a side, not prominent ladder-like cross venation between them, obscure network in intervals; stipules prominent, orbicular, united at base, free parts spreading, leaf-like, tardily dehiscent; peduncles lateral, one at a node, leaf-opposed, replacing one leaf of the pair at a fertile node; flowers with hypanthia connate in a broadly cylindric to ovoid head, white; calyx reduced to an entire ring; corolla hypocrateriform, tube slightly dilated upward somewhat bearded within, lobes 5 – 6, ovate, anthers included, attached below sinuses, style with 2 recurved stigmatic branches well-exserted, flowering progressive, buds and several open flowers at top, buds rounded at apex, lobes valvate; fruit a fleshy syncarp with many stones, becoming white, soft, finally disagreeably putrid, "maa".

Pantropic strand and lowland species, with many medicinal and practical uses, very common, especially at lower elevations on Maupiti.

Raynal 17833 (p. 1337); Morris 21 (US); Fosberg 64862 (US).

Pentas Benth.

A herbaceous or somewhat shrubby group, mainly African, stems branched at base, leafy, bearing a corymbiform cyme of attractive mauve, red, or other colors salverform flowers. At least two species are found in cultivation in warm countries.

Pentas lanceolata (Forssk.) DeFlers

Erect herb to 1 m, flowers in terminal corymbiform cymes, corollas salverform, mauve, cultivated ornamental.

Fosberg 64905 (US).

Timonius DC.

Shrubs and trees; leaves simple, opposite; stipules foliaceous, flat or rolled around bud; flowers unisexual, 3- to many-flowered, pistillate on solitary pedicels or triflorous cymes; calyx usually reduced to teeth, 4 – 6 or 7 in number, corollas salverform with 4 – 7 lobes; stamens inserted near summit of tube, ovary 5 – 7 or more locular, style correspondingly branched; fruit a black drupe with 5 – 7 or more vertical rows of small stones, the rows radially arranged.

Many species, spread through the Indo-Pacific tropics, one in eastern Polynesia.

Timonius polygamus (Forst. f.) Seem.

Small to medium rather slender shrub, opposite branching, twigs very minutely sericeous; leaves variable in size from plant to plant, obovate, apex obtusish, base cuneate to more abruptly contracted to a short petiole, 4 – 5 not very prominent veins on a side; stipules triangular, distally carinate, keel excurrent to a short cusp, deciduous from second or third node; flowers dioecious, staminate in axillary cymes, pistillate solitary on axillary peduncles; staminate cymes shorter than leaves, 2 – 4 times branched, a subsessile or very shortly pedicellate flower in each fork, branchlets ending in triads; flowers white; calyx with 4 – 6 unequal triangular teeth; corolla hypocrateriform, tube slender, less than 1 cm long, lobes 4 – 6, lanceolate, blunt, spreading, tube and lobes puberulent without; anthers linear,

attached in throat, included; pistillate much shorter than tube; pistillate flower sessile on summit of an axillary peduncle about 1 cm or less long, ovary subtended by an articulation with 2 minute fleshy triangular bractlets, ovary (hypanthium) urceolate or turbinate-subglobose, greater in diameter than corolla tube, calyx of six minute unequal triangular lobes, persistent on fruit; corolla tube about 5 mm or less long, thicker than in staminate flower, lobes 6, spreading, narrowly ovate-oblong, tube and lobes minutely puberulent without; stigma lobes lanceolate, erect, shortly exserted; peduncle elongating to 1.5–2 cm or more, in fruit, fruit depressed globose or very broadly obovoid, glossy black, fleshy; stones in 6 or more vertical rows of several, radiating outward.

A widespread strand species in southern Polynesia, notable for its variation in vegetative characters. Common in shrub layer in coconut plantations and in thickets and clearings.

Fosberg 64750 (US), 64753 (US), 64784 (US), 64785 (US), 644806 (US), 64978 (US).

GOODENIACEAE

Herbs and shrubs, rarely small trees, leaves simple, alternate or rarely opposite ; flowers in small cymes or racemes or solitary, axillary, calyx 5-lobed or toothed; corolla gamopetalous, 5-lobed, often bilabiate or split down one side; stamens usually free or anthers coherent in a ring, ovary usually inferior, usually bilocular, ovules 1 to many in a locule; style with a cup-like structure below the stigma; fruit a drupe, berry, nut or capsule.

The family is mainly Australian but one genus has radiated through the Pacific, one species in the Atlantic.

Scaevola L.

Shrubs, rarely small trees or herbs; leaves alternate or rarely opposite, often with an axillary tuft of long silky hairs, flowers in small axillary cymes or on solitary axillary peduncles, corolla gamopetalous, with five somewhat reflexed lobes, tube split down one side, stamens free, ovary inferior, bilocular, one basal ovule in each cell, fruit a drupe with an indurate stone.

Scaevola sericea var. tuamotuensis (St. John) Fosb.

Scaevola taccada var. tuamotuensis St. John

Rounded shrub, with "terminalioid" branching habit (branch prolonging by a lateral branch from the lower side of branch somewhat back from upward curving growing tip, curving forward and producing another similar branch), other varieties reaching large shrub or even small tree size, this one low-rounded, tending to creep; leaves obovate to spatulate, apex rounded, sessile, usually with a tuft of white hair in axil, leaf and branch surface glabrous (in this variety); flowers single on axillary pedicel or on several-flowered bracteolate cymes; ovary inferior, calyx lobes small, linear or lanceolate, blunt; corolla with tube split down one side, lobes spreading fan-wise, flower appearing torn in half, corolla lobes with very thin membranous broad pale yellowish borders (white or purple in other varieties), stamens 5, filaments finely filiform; style curved near apex, fruit a soft white subglobose to globose drupe, the stone corky externally, with 2 locules, one seed in each, and two apparent vestigial locules.

This species is a widespread one in Indo-Pacific region, especially in strand situations; the variety tuamotuensis from Society Islands eastward through the Tuamotus; common on motus of Maupiti.

Fosberg 64807 (US), 64872 (US).

ASTERACEAE (Compositae)

Habit various, predominantly herbaceous; leaf arrangement opposite or alternate or even both on same plant, simple or pinnately compound or both on same plant; true stipules none; flowers aggregated in heads (capitula) of 1-many flowers on a receptable, surrounded by an involucure of 1-several whorls or spirals of bracts (phyllaries), in some groups with a chaff-like bract subtending each flower on the receptacle; flowers of 2 sorts, those with corollas with radial symmetry (disk flowers) and those with corolla strap-shaped or fan-shaped split down one side (ligulate flowers or ray-flowers),

some groups with only disk flowers, some with only ray flowers, more usual patterns with one or more circles of ray-flowers surrounding an often large number of disk-flowers, ovary inferior, one basal ovule, calyx reduced to chaff-like scales or to bristles, awns or hairs called pappus or lacking, corolla lobes 4 or 5, stamens 5, filiments free, anthers joined forming a tube surrounding the style, the latter with 2 branches that exceed the anther tube, usually becoming reflexed; fruit a one-seeded indurate matured ovary called an achene (more correctly a cypsela), which may or may not be crowned by a persistent pappus which may serve as a dispersal mechanism either by attaching to animals hair or by wind.

Said to be the largest family of plants, poorly represented in Pacific Island area except for weedy exotics. A dozen or so species in Maupiti all probably introduced by man.

Bidens L.

Mostly herbs, Pacific islands native species somewhat or quite woody, with a resinous odor; leaves opposite, simple or pinnately compound or trifoliolate; heads terminal on branches, involucre of rather few phyllaries spirally arranged; rays usually present, occasionally absent or obscure; disk yellow, rays yellow or white, pappus of 2–3 short stiff awns, usually barbed, rarely lacking, achenes linear.

Bidens pilosa L. forma pilosa

Erect somewhat resinous smelling herb, leaves opposite, simple to pinnately compound, then with 3 or usually 5 ovate leaflets, margins serrulate; heads pedunculate, somewhat open paniculate, heads less than 1 cm high, with 1 series of spatulate green obtuse phyllaries, no ligulate flowers, achenes linear, with 2–3 stiff retrorsely barbed awns.

Pantropical weed; on Maupiti one of the most ubiquitous and common plants, dispersed everywhere in open and semi-open ground by man, by means of its awned fruits which cling to clothing.

Fosberg 64886 (US).

Bidens pilosa f. minor (Bl.) Sherff

Differs from f. pilosa in the presence of several very small white ligulate flowers in each head.

Found occasionally on Maupiti.

Fosberg 64907 (US).

Blumea D.C.

Aromatic herbs, usually pubescent or woolly, leaves alternate; heads in a corymbiform panicle, involucre of many overlaping narrow phyllaries, rays none, disk-flowers many, very slender, pappus of short bristles, heads yellow or purple.

Blumea sinuata (Lour.) Merr.
Blumea laciniata (Roxb.) DC.

Erect herb to 1 m tall; rather wooly; leaves spatulate-ovate, cuneate at base, obtuse at apex, irregularly dentate, panicles spike-like; involucres of several subequal series of lanceolate, margined bracts, disk yellow.

Widely distributed in SE Asia and the western Pacific, a rather recent arrival in the Society Islands, rare in weedy lowlands and coastal strip on Maupiti.

Fosberg 64763 (US).

Conyza Less.

Herbs with alternate leaves, panicles of small heads, involucres of several series of subequal narrow

phylleries, ray flowers very reduced, disk flowers small, yellow, pappus of rather short bristles.

Conyza bonariensis (L.) Cronq.
Erigeron bonariensis L.

Tall herb to 2 or even 3 m, linear serrate alternate pubescent leaves, dome-shaped panicles of small heads with almost obsolete ligules, achenes with light brown pappus bristles.

Widespread tropical and temperate zone weed, on Maupiti common in disturbed ground, especially on motus.

Fosberg 64869 (US).

Elephantopus L.

Usually more or less hirsute herbs with few rather large alternate leaves, heads narrow, aggregated in small tight clusters enclosed by several broad sessile bracts at tips of slender branches, ray flowers none, disk flowers with straight awn-like pappus bristles.

Elephantopus mollis HBK n.v. ava'ava teitei

Tall, slender, sparsely branched stiffly hirsute or hispid herbs, disk flowers pale lavender; vary fast-growing.

A weed of tropical American origin, now one of the commonest plants on Maupiti, from sea level to the high mountains.

Raynal 17864 (p. 1338); Fosberg 64826 (US).

Emilia Cass

Tender weak-stemmed herbs, usually rather pale or glaucous green; leaves alternate, lobed, terminal lobe usually triangular, heads solitary or in loose few-flowered clusters on long peduncles; involucre of one whorl of linear, coherent phyllaries; ray-flowers none.

Emilia fosbergii Nicolson n.v. ma'a rapiti

Leaves and stems slightly glauceous green, flowers red considerably exceeding involucre.

A widespread tropical and subtropical plant of uncertain origin, possibly a very successful escape from cultivation, common generally on
Maupiti.

Raynal 17866 (p. 1338); Fosberg 64878 (US), 64882 (US).

Emilia sonchifolia (L.) DC.

Slender, leaves and stems glaucous, somewhat purplish; head narrow, flowers purple, scarcely exceeding involucre.

A very widespread plant of disturbed or open ground, occasional on Maupiti, much less common than its congener noted above.

Fosberg 64792 (US).

Gaillardia Foug.

Weak-stemmed, branched herbs, leaves alternate broadly linear, entire or lobed, heads terminal on long peduncles, involucre spreading, one series of conspicuous ray-flowers, disk globose, pappus of coarse bristles.

Gaillardia pulchella Foug.

Grayish green somewhat hirsute herbs, ray flowers yellow to dark purplish red, usually with yellow tip. Planted ornamental.
Fosberg 64908 (US).

Pluchea Cass.

Herbs or usually shrubs, leaves alternate, heads many in corymbiform clusters, pinkish or purplish, rays lacking. Pantropical, few species.

Pluchea symphytifolia (Mill.) Gillis

Tropical American shrubby species, very weedy and since the 1930's rapidly spreading in the Pacific; seen in Maupiti only in interior of Motu Auira.
Fosberg 64754 (US).

Pseudelephantopus Rohr.

Tough wiry herbs, leaves few alternate, heads arranged in a terminal spike, narrow, rays lacking, disk flowers white or dark lavender, pappus of several unequal awns, the longest with an s-shaped curve near the middle. One tropical species, now widely distributed.

Pseudelephantopus spicatus (B. Juss.) Vahl. n.v. ava'ava ha'avare; rau'ara nu'a

Pantropical weed, in Maupiti it is occasional on weedy slopes, road-sides, and disturbed places.
Raynal 17822 (p. 1337); Fosberg 64827 (US); Morris 22 (US).

Synedrella Gaertn.

Erect herbs with opposite leaves; heads axillary, 2 at a node; involucres narrow, erect, of chaff-like phyllaries, few flowered; achenes margined, margins sharply dentate, pappus of 2 stout subulate spines.

Synedrella nodiflora (L.) Gaertn. n.v. tauatini (mille)

A pantropical weed, usually less than 0.5 m tall ; on Maupiti reaching a height of 2 m, both on Motu Auira and on coastal strip.
Raynal 17823 (p. 1337), Fosberg 64830 (US).

Vernonia Schreb.

Herbs, shrubs or trees, leaves simple, alternate, heads in corymbiform panicles; involucres of several to usually many imbricate series of phyllaries; disk flowers only, corolla regular, 5 lobed, usually purple, sometimes pink or white, pappus of capillary bristles but with an outer series of tiny scales.

An enormous mostly tropical genus, one pantropical herbaceous species common in Polynesia, including Maupiti.

Vernonia cinerea (L.) Less. sensu lato n.v. little ironweed

A slender simple to sparingly branched puberulent herb; leaves alternate, obovate, slightly crenate margined, apex obtuse, base narrowed to a slender petiole; inflorescence an open irregularly branched corymbiform panicle, heads small, cylindric-ovoid, phyllaries imbricate, varying in length, lance-oblong, sharply acuminate, florets 15–20, bright purple, corolla lobes 5, pappus bristles white, elongating, exserted to almost twice length of involucre, caducous from mature achene leaving a short crown, achene cylindric, antrorse pubescent, involucre reflexed in age.

A ubiquitous Indo-Pacific weed, probably of Indian or Ceylonese origin, now pantropical. Pacific plants with small heads have been described as var. parviflora.

Widespread very common Indo-Pacific weed, frequent in lowlands and on motus in Maupiti.

Raynal 17868 (p 1338); Fosberg 64786 (US)

ATOLL RESEARCH BULLETIN

NO. 295

FLORA OF THE GILBERT ISLANDS, KIRIBATI, CHECKLIST

BY

F. RAYMOND FOSBERG AND MARIE-HELENE SACHET

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FLORA OF THE GILBERT ISLAND, KIRIBATI, CHECKLIST

BY

F. Raymond Fosberg* and Marie-Hélène Sachet

The Gilbert Islands are a north-south chain of low coral islands, lying across the equator at about 172°-177° E longitude. The atolls, from north to south are Little Makin, Butaritari, Marakei, Abaiang, Tarawa, Maiana, Kuria, Aranuka, Abemama, Nonouti, Tabiteuea, Onotoa, Beru, Nikunau, Tamana, and Arorai. They are densely populated, and were under British Colonial Government until 1979, when they were granted independence, and now are the principal archipelago in the new republic of Kiribati.

The following list is compiled from specimens that we have examined and from published records. Listed are all species that we have information on occurrence in the Gilbert Islands with islands listed where they have been found. We cannot vouch for the accuracy of published records. The paucity of species from many of the islands give an idea of how poorly known is the flora of the Gilbert Group. Some of the records are not supported by specimens and many of the specimens that exist are inadequate for accurate identification. New collections with better than usual data on locality, occurrence, and such features of the plants as do not show on dried specimens are greatly to be desired. A special effort should be made to collect on islands other than Tarawa, Butaritari and Onotoa. Probably most of the species growing spontaneously in the group are known, but the lists for most of the individual islands are woefully incomplete. The present list gives a reasonably adequate idea of the present state of knowledge of the flora. It should be emphasized that the list is preliminary and that more collections will result in more complete lists and, eventually, in a descriptive flora.

Since the main list was compiled we have been privileged to examine a comprehensive list of Gilbertese vernacular plant names, assembled by Prof. Randy Thaman, of the University of the South Pacific, Suva, Fiji. Although this is published in the following paper, we have extracted a number of botanical names of species not included in our list. We have inserted these in our list, for completeness sake, even though we have not examined specimens. We thank Dr. Thaman for these additions.

PSILOTACEAE

Psilotum Sw.

Psilotum nudum (L.) Beauv.
  Lycopodium nudum L.
  Psilotum triquetrum Sw.
    Gilbert Is.: Butaritari; Tarawa

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POLYPODIACEAE

*Adiantum L.

*Adiantum raddianum Presl
Adiantum cuneatum Langsd. & Fisher
Gilbert Is.: Tarawa

Asplenium L.

Asplenium nidus L. sensu lato
Gilbert Is.: Tarawa

Nephrolepis Schott
Nephrolepis biserrata (Sw.) Schott ?
Gilbert Is.

Nephrolepis hirsutula (Forst. f.) Presl
Polypodium hirsutulum Forst. f.
Nephrolepis cordifolia sensu Catala non (L.) Presl
Nephrolepis biserrata sensu auct. non (Sw.) Schott?
Gilbert Is.: Abaiang; Tarawa; Butaritari

Nephrolepis cordifolia (L.) Presl see Nephrolepis hirsutula (Forst. f.) Presl

Polypodium L.

Polypodium scolopendria Burm. f.
Phymatodes scolopendria (Burm. f.) Ching
Polypodium phymatodes L.
Dryostachyum drynarioides sensu Schum. & Laut. non (Hook.) Kuhn
Microsorium scolopendria (Burm. f.) Copel.
Gilbert Is.: Butaritari; Tarawa

Pteris L.

Pteris tripartita Sw.
Pteris marginata Bory
Syngramma quinata sensu. Schum. & Laut. non (Hook.) Carr.
Gilbert Is.: Butaritari

CYCADACEAE

Cycas L.

Cycas circinalis L.
Cycas rumphii Miq.
Gilbert Is.: Tarawa; Butaritari

PANDANACEAE

Pandanus L.

Pandanus tectorius Park. sensu latissimo, including many varieties and cultivars.
Gilbert Is.: Tarawa; Abemama; Tabiteuea; Onotoa; Beru; Nikunau; Arorai (and probably all other islands)

POTAMOGETONACEAE

Ruppia L.

Ruppia maritima var. pacifica St. John & Fosb.
Gilbert Is.: Nikunau

HYDROCHARITACEAE

Thalassia Banks ex Koenig

Thalassia hemprichii (Ehrenb.) Aschers.
Schizotheca hemprichii Ehrenb.
Cymodocea serrulata sensu Catala non (Ehrenb.) Aschers.
Gilbert Is.: Tarawa; Onotoa, Nonouti

POACEAE (GRAMINEAE)

Bambusa Schreb.
Bambos Retz.

*Bambusa sp.
Gilbert Is.: Marakei

Cenchrus L.

Cenchrus echinatus L.
Gilbert Is.: Butaritari; Marakei; Tarawa; Nonouti; Tabiteuea; Onotoa

Chloris Sw.

*Chloris inflata Link
Chloris barbata sensu Sw. non (L.) Sw.
Gilbert Is.: Tarawa; Abemama

Cynodon Pers.
Capriola Adans.

*Cynodon dactylon (L.) Pers.
Panicum dactylon L.
Capriola dactylon (L.) 0. Ktze.
Gilbert Is.: Tarawa

*Dactyloctenium Willd.

*Dactyloctenium aegyptium (L.) Willd.
Cynosurus aegyptius L.
Dactyloctenium aegyptiacum (L.) Willd. (orth. mut.)
Gilbert Is.: Tarawa

Digitaria Hall.
  Syntherisma Walt.
  Tricachne Nees

Digitaria pacifica Stapf
  Digitaria stenotaphrodes sensu auct. Micronesia non (Nees) Stapf
    Gilbert Is.

Digitaria radicosa (J.S. Presl) Miq.
  Panicum radicosum J.S. Presl
  Digitaria timorensis (Kunth) Balansa
    Gilbert Is.: Tarawa?

Digitaria setigera Roth in R. & S. (sensu lato, varieties not sorted out).
  Panicum pruriens Fisch. ex Trin.
  Digitaria pruriens (Fisch. ex Trin.) Buse
  Digitaria microbachne (J.S. Presl) Henr.
  Digitaria pruriens var. microbachne (J.S. Presl) Fosb.
    Gilbert Is.: Butaritari; Marakei; Tarawa; Abemama; Nikunau

Digitaria stenotaphrodes (Nees) Stapf see Digitaria pacifica Stapf for Gilbert Is. record.

*Echinochloa Beauv.

*Echinochloa crus-galli var. austro-japonensis Ohwi
    Gilbert Is.: Butaritari

*Eleusine Gaertn.

*Eleusine indica (L.) Gaertn.
  Cynosurus indicus L.
    Gilbert Is.: Butaritari; Marakei; Tarawa; Abemama; Tabiteuea

Eragrostis N. M. v. Wolf

*Eragrostis amabilis (L.) W. & A. ex Hook.
  Eragrostis tenella (L.) Beauv. ex R. & S.
  Poa tenella L.
  Eragrostis plumosa (Retz.) Link
  Eragrostis amabilis (L.) W. & A. ex Hook.
    Gilbert Is.: Butaritari; Marakei; Tarawa; Nonouti; Tabiteuea; Onotoa

Eragrostis whitneyi Fosb.
    Gilbert Is.: Onotoa

*Eustachys Desv.
  Chloris sect. Eustachys (Desv.) Reich.

*Eustachys petraea (Sw.) Desv.
  Chloris petraea Sw.
    Gilbert Is.: Tarawa

Lepturus R. Br.
  Monerma Beauv.

Lepturus pilgerianus Hans. & Potzt.
Gilbert Is.: Tarawa

Lepturus repens (Forst. f.) R. Br.
Rottboellia repens Forst. f.
Monerma repens (Forst. f.) Beauv.
Gilbert Is.

Lepturus repens (Forst.f.) R. Br. var. repens
Lepturus acutiglumis sensu Luomala non Steud.
Gilbert Is.: Onotoa

Lepturus repens var. repens × var. subulatus Fosb.
Gilbert Is.: Butaritari; Tabiteuea; Onotoa

Lepturus repens var. cinereus (Burcham) Fosb.
Lepturus cinerea Burcham
Gilbert Is.: Tarawa

Lepturus repens var. maldenensis F. Br.
Gilbert Is.

Lepturus repens var. septentrionalis Fosb.
Lepturus mildbraedianus H. & P.
Gilbert Is.: Marakei; Tarawa

Lepturus repens var. subulatus Fosb.
Gilbert Is.: Butaritari; Marakei; Abaiang; Tarawa; Nonouti;
Tabiteuea; Onotoa

Panicum L.

Panicum distachyon L.
Brachiaria distachya (L.) Stapf
Gilbert Is.: Tarawa

Panicum subquadriparum Trin.
Brachiaria subquadripara (Trin.) Hitchc.
Gilbert Is.: Tarawa

Paspalum L.

Paspalum distichum L.
Paspalum vaginatum Sw.
Paspalum littorale R. Br.
Gilbert Is.: Butaritari (Makin); Marakei; Tarawa; Nikunau

*Pennisetum L. Rich.

Pennisetum ciliare (L.) Link
Gilbert Is.: Tarawa

*Pennisetum polystachion (L.) Schult.
Panicum polystachion L.

Pennisetum setosum sensu auct. non (Sw.) L. C. Rich.
Gilbert Is.: Butaritari

*Pennisetum purpureum Schumach.
Pennisetum merkeri Leeke
Gilbert Is.: Tarawa

Saccharum L.

*Saccharum officinarum L.
Gilbert Is.: Butaritari; Marakei; Tarawa

Sporobolus R. Br.

Sporobolus diander (Retz.) Beauv.
Agrostis diandra Retz.
Gilbert Is.: Tarawa

Sporobolus fertilis (Steud.) Clayton
Agrostis fertilis Steud.
Gilbert Is.: Butaritari

Stenotaphrum Trin.

Stenotaphrum micranthum (Desv.) Hubb.
Ophiurinella micrantha Desv.
Stenotaphrum subulatum Trin.
Gilbert Is.: Butaritari; Marakei; Tarawa; Onotoa; Beru

Thuarea Pers.

Thuarea involuta (Forst.f.) R. Br. ex R. & S.
Ischaemum involutum Forst. f.
Gilbert Is.: Abaiang; Tarawa

Zea L.

Zea mays L.
Gilbert Is.

CYPERACEAE

Cyperus L.

Cyperus brevifolius (Rottb.) Hassk.
Kyllinga brevifolia Rottb.
Gilbert Is.: Nonouti

Cyperus compressus L.
Gilbert Is.: Tarawa

Cyperus javanicus Houtt.
Gilbert Is.: Butaritari; Marakei; Tarawa

Cyperus kyllingia Endl.

Gilbert Is.: Butaritari

Cyperus laevigatus L.
Scirpus mucronatus sensu Guillaumin non L.
Gilbert Is.: Marakei; Abaiang; Tabiteuea; Onotoa; Nikunau

Cyperus odoratus L. (not separated to variety)
Gilbert Is.: Tabiteuea

Cyperus odoratus L. var. odoratus
Gilbert Is.: Butaritari; Tarawa

Cyperus polystachyos Rottb.
Gilbert Is.: Butaritari; Marakei; Tarawa

Cyperus rotundus L.
Cyperus hexastachyos Rottb.
Gilbert Is.: Tarawa

Eleocharis R. Br.
Heleocharis Lestib.

Eleocharis acicularis (L.) R. & S.
Scirpus acicularis L.
Gilbert Is.: Onotoa

Eleocharis geniculata (L.) R. & S.
Scirpus geniculatus L.
Eleocharis obtusa sensu Moul. non (Willd.) Schult.
Gilbert Is.: Butaritari; Marakei; Tarawa; Onotoa

Fimbristylis Vahl

Fimbristylis cymosa R. Br. (sensu lato)
Fimbristylis cymosa var. umbellato-capitata (Steud.) Hillebr.
Fimbristylis cymosa var. pycnocephala (Hillebr.) Kük. ex F. Brown
Fimbristylis cymosa var. microcephala F. Br.
Fimbristylis atollensis St. John
Fimbristylis complanata sensu Guillaumin non Link
Gilbert Is.: Butaritari; Marakei; Abaiang; Tarawa; Nonouti; Tabiteuea; Onotoa

Fimbristylis dichotoma (L.) Vahl (sensu lato)
Gilbert Is.: (Kiribati)

PALMAE

*Cocos L.

Cocos nucifera L.
Gilbert Is.: Little Makin; Butaritari; Abaiang; Tarawa; Kuria; Aranuka; Abemama; Nonouti; Tabiteuea; Onotoa; Nukunau; Tamana; Arorai

Cocus nucifera var. (unbranched inflorescence)

Gilbert Is.

*Pritchardia Seem. & Wendl.

Pritchardia pacifica Seem. & Wendl.
Eupritchardia pacifica (Seem. & Wendl.) 0. Ktze.
Gilbert Is.

ARACEAE

*Alocasia (Schott) G. Don

*Alocasia macrorrhiza (L.) G. Don
Arum macrorrhizon L.
Alocasia indica (Roxb.) Spach
Gilbert Is.

Caladium

Caladium bicolor (W. Ait.) Vent.
Gilbert Is.: Butaritari; Tarawa

Colocasia Schott

Colocasia esculenta (L.) Schott
Arum esculentum L.
Gilbert Is.: Butaritari?; Tarawa; Tabiteuea

Cyrtosperma Griff.
Arisacontis Schott

Cyrtosperma chamissonis (Schott) Merr.
Arisacontis chamissonis Schott
Gilbert Is.: Nonouti; Tabiteuea; Onotoa; Nikunau

*Xanthosoma Schott

*Xanthosoma sagittifolium (L.) Schott
Gilbert Is.

BROMELIACEAE

Ananas Mill.

Ananas comosus (L.) Merr.
Gilbert. Is.

COMMELINACEAE

*Rhoeo Hance

*Rhoeo spathacea (Sw.) Stearn
Tradescantia spathacea Sw.
Tradescanthia discolor L'He'r.
Rhoeo discolor (L'He'r.) Hance

Gilbert Is.: Abaiang

LILIACEAE
(sensu latissimo incl. Agavaceae, Amaryllidaceae)

*Agave L.

*Agave rigida var. sisalana (Perrine) Engelm.
Agave sisalana Perrine
Agave vivipara L. pro parte
Gilbert Is.: Abaiang; Tarawa; Nikunau; Arorai

*Agave americana L.
Gilbert Is.

*Allium L.

*Allium ascalonicum L.
Gilbert Is.

*Allium cepa L. s.l. incl. vars.
Allium cepa var. viviparum Metz
Allium fistulosum L. var. fistulosum
Allium fistulosum var. giganteum Mak.
Gilbert Is.

*Allium fistulosum L.
Gilbert Is.

Cordyline R. Br.

Cordyline fruticosa (L.) Chev.
Convallaria fruticosa L.
Cordyline terminalis (L.) Kunth
Taetsia fruticosa (L.) Merr.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea

*Crinum L.

*Crinum asiaticum var. pedunculatum (R. Br.) Fosb. & Sachet

*Crinum asiaticum var. not determined
Gilbert Is.: Tarawa

*Crinum augustum Ker-Gawl. ?
Gilbert Is.

*Crinum spp. (sterile, undeterminable)
Gilbert Is.: Tarawa; Onotoa

*Dracaena Vand. ex L.
Crinum pedunculatum R. Br.
C. australe Don
Gilbert Is.

*Dracaena sp.
Gilbert Is.: Tarawa

*Gloriosa L.

*Gloriosa superba L.
Gilbert Is.: Tarawa

*Hymenocallis Salisb.

*Hymenocallis littoralis (Jacq.) Salisb.
Pancratium littorale Jacq.
Pancratium americanum Miller
Gilbert Is.: Tarawa

*Zephyranthes Herb.
Atamosco Adans.

*Zephyranthes rosea Lindl.
Atamosco rosea (Lindl.) Greene
Gilbert Is.: Butaritari; Tabiteuea

TACCACEAE

Tacca Forst.

Tacca leontopetaloides (L.) 0. Ktze.
Leontice leontopetaloides L.
Tacca pinnatifida Forst.
Gilbert Is.: Butaritari; Tarawa

MUSACEAE

Musa L.

*Musa X sapientum L.
Musa paradisiaca ssp. sapientum (L.) O. Ktze.
Gilbert Is.

ZINGIBERACEAE

Curcuma L.

Curcuma longa L.
Curcuma domestica Val.
Gilbert Is.

CANNACEAE

*Canna L.

*Canna indica L.
Gilbert Is.: Tarawa

CASUARINACEAE

Casuarina L.

Casuarina equisetifolia L.
Casuarina litorea L. var. litorea
Gilbert Is.: Butaritari (Makin); Tarawa

MORACEAE

Artocarpus Forst.

Artocarpus altilis (Park.) Fosb.
Sitodium altile Park.
Artocarpus incisus (Thunb.) L. f.
Artocarpus communis Forst.
Gilbert Is.: Butaritari; Marakei; Abaiang; Tarawa; Kuria; Abemama; Tabiteuea; Onotoa; Beru; Nikunau; Arorai

Artocarpus altilis X mariannensis
Gilbert Is.: Tarawa

*Artocarpus heterophyllus Lam.
Gilbert Is.: Tabiteuea

Artocarpus mariannensis Trec.
Gilbert Is.: Tarawa

Ficus L.

Ficus benghalensis L.
Gilbert Is.: Tarawa

*Ficus carica L.
Gilbert Is.: Abemama; Tabiteuea

Ficus prolixa Forst. f.
Gilbert Is.: Abaiang

Ficus tinctoria Forst. f. var. tinctoria
Ficus tinctoria Forst. f. ssp. tinctoria
Gilbert Is.: Onotoa

Ficus tinctoria var. neo-ebudarum (Summerh.) Fosb.
Ficus neo-ebudarum Summerh.
Ficus philippinensis sensu Diels, Kanehira non Miq.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea

URTICACEAE

Laportea Gaud. (nom cons.)
Fleurya Gaud.

Laportea ruderalis (Forst. f.) Chew
Urtica ruderalis Forst. f.

Fleurya ruderalis (Forst. f.) Gaud. ex Wedd.
Gilbert Is.: Little Makin; Butaritari; Marakei; Abaiang; Tarawa; Onotoa

*Pilea Lindl.

*Pilea microphylla (L.) Liebm.
Parietaria microphylla L.
Gilbert Is.: Butaritari; Tarawa

Pipturus Wedd.

Pipturus argenteus (Forst. f.) Wedd. var argenteus
Urtica argentea Forst. f.
Boehmeria albida sensu Endlicher p.p. non Hook. & Arn.
Gilbert Is.: Butaritari; Abaiang

POLYGONACEAE

*Antigonon Endl.

*Antigonon leptopus H. & A.
Gilbert Is.: Tarawa

*Coccoloba L.

*Coccoloba uvifera (L.)L.
Gilbert Is.: Tarawa; Tabiteuea

AMARANTHACEAE

Achyranthes L.

Achyranthes canescens R. Br.
Achyranthes velutina H. & A. at least for Micronesian records.
Gilbert Is.

Alternanthera Forsk.

*Alternanthera ficoidea var. bettzickiana (Regel) Backer
Telanthera bettzickiana Regel
Alternanthera versicolor Regel
Alternanthera bettzickiana (Regel) Nicholson
Gilbert Is.: Tarawa

*Amaranthus L.
Euxolus Raf.

*Amaranthus dubius Mart. ex Thell.
Amaranthus gracilis sensu Catala and Guillaumin, non Desf.
Gilbert Is.: Tarawa

*Amaranthus viridis L.
Gilbert Is.

Gomphrena L.

Gomphrena L.

*Gomphrena globosa L.
Gilbert Is.: Tarawa

NYCTAGINACEAE

Boerhavia L.

Boerhavia albiflora Fosberg
Gilbert Is.: Onotoa

Boerhavia repens L.
Boerhavia hirsuta sensu auct. non L.
Boerhavia diffusa sensu auct. plur. non L.
Gilbert Is.: Tarawa; Abemama; Tabituea; Onotoa

Boerhavia tetrandra Forst.
Boerhavia diffusa var. tetrandra (Forst.) Heimerl
Boerhavia repens sensu Catala, Guillaumin, non L.
Gilbert Is.: Butaritari; Marakei; Tarawa; Onotoa

*Bougainvillea Comm. ex Juss.

*Bougainvillea glabra Choisy
Gilbert Is.: Tarawa

*Bougainvillea spectabilis Willd.?
Gilbert Is.: Tarawa

*Mirabilis L.

*Mirabilis jalapa L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea

Pisonia L.

Pisonia grandis R. Br.
Ceodes umbellifera sensu St. John 1948 non J.R. & G. Forst.
Gilbert Is.: Little Makin; Butaritari; Marakei; Tarawa; Tabiteuea; Onotoa

AIZOACEAE

Sesuvium L.

Sesuvium portulacastrum var. griseum Deg. & Fosb.
Gilbert Is.: Nukunau

PORTULACACEAE

Portulaca L.

Portulaca australis Endl.
Portulaca samoensis v. Poelln.
Portulaca tuberosa sensu auct. non Roxb.

Portulaca quadrifida sensu auct. non L.
Gilbert Is: Marakei; Abaiang; Tarawa; Tabiteuea; Onotoa

Portulaca lutea Sol. ex Forst. f.
Portulaca oleracea sensu Guillaumin, non L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Onotoa; Abaiang

Portulaca oleracea var. granulato-stellulata v. Poelln. (for all or most Micronesian records of Portulaca oleracea L.)
Portulaca retusa Engelm.
Gilbert Is.: Butaritari; Tarawa; Marakei; Nonouti; Onotoa

BASELLACEAE

Basella L.

*Basella rubra L.
Gilbert Is.

LAURACEAE

Cassytha L.

Cassytha filiformis L.
Gilbert Is.: Butaritari; Tarawa; Nonouti; Tabiteuea; Onotoa

HERNANDIACEAE

Hernandia L.

Hernandia sonora L.
Hernandia ovigera sensu auct. non L.
Hernandia nymphaeaefolia (Presl) Kubitzki
Gilbert Is.: Butaritari; Abaiang; Tarawa; Tabiteuea; Onotoa

CRUCIFERAE

Brassica L.

Brassica chinensis Juss. var. chinensis
Gilbert Is.

Brassica juncea (L.) Czern. & Cossin
Gilbert Is.

*Brassica oleracea var. bullator DC.
Gilbert Is.

*Raphanus L.

*Raphanus sativus L. var. sativus
Gilbert Is.

CAPPARIDACEAE

Crateva L.

Crateva speciosa Volk.
Crateva religiosa sensu auct. Micr. non Forst. f.
Gilbert Is.: Tarawa

CRASSULACEAE

*Kalanchoe Adans.

*Kalanchoe pinnata (Lam.) Pers.
Cotyledon pinnatum Lam.
Bryophyllum pinnatum (Lam.) Kurz.
Bryophyllum calycinum Salisb.
Gilbert Is.: Tarawa; Tabiteuea

*Kalanchoe tubiflora (Harvey) Hamet
Bryophyllum tubiflorum Harvey
Gilbert Is.: Tarawa

ROSACEAE

Rosa L.

*Rosa multiflora Thunb. hort. var.
Gilbert Is.: Tarawa

MIMOSACEAE

*Acacia Willd.

*Acacia farnesiana (L.) Willd.
Mimosa farnesiana L.
Gilbert Is.: Tarawa; Nikunau

Leucaena Benth.

Leucaena leucocephala (Lam.) de Wit
Mimosa leucocephala Lam.
Leucaena glauca sensu auct. plur. non (L.) Benth.
Gilbert Is.: Tarawa

*Prosopis L.

*Prosopis pallida (H. & B. ex Willd.) HBK.
Acacia pallida H. & B. ex Willd.
Gilbert Is.: Tarawa

CAESALPINIACEAE

Caesalpinia L.

Caesalpinia bonduc (L.) Roxb.
Guilandina bonduc L.
Gilbert Is.: Tabiteuea

*Cassia L.

*Cassia occidentalis L.
Gilbert Is.: Butaritari; Tarawa

*Delonix Raf.

*Delonix regia (Boj.) Raf.
Poinciana regia Boj.
Gilbert Is.: Tarawa; Aranuka; Onotoa; Beru

*Tamarindus L.

*Tamarindus indica L.
Gilbert Is.: Tarawa

FABACEAE

Canavalia Adans.

*Canavalia cathartica Thou.
Canavalia microcarpa (DC.) Piper
Gilbert Is.: Tarawa

*Clitoria L.

*Clitoria tarnatea L.
Gilbert Is.: Tarawa

*Crotalaria L.

*Crotalaria retusa L.
Gilbert Is.

*Crotalaria spectabilis Roth
Gilbert Is.: Tarawa

Demodium Desv.

*Desmodium heterocarpon (L.) DC.
Desmodium purpureum (Roxb.) H.& A.
Gilbert Is.

Desmodium tortuosum (Sw.) DC.
Gilbert Is.: Tarawa

Dioclea HBK.

Dioclea reflexa Hook. f.
Gilbert Is.: Tabiteuea (drift seeds)

*Gliricidia HBK.

*Gliricidia sepium (Jacq.) Steud.

Robinia sepium Jacq.
Gilbert Is.: Tarawa

*Inocarpus Forst.

*Inocarpus fagifer (Park.) Fosb.
Aniotum fagiferum Park.
Inocarpus edulis Forst.
Gilbert Is.

*Mucuna Adans.

*Mucuna gigantea (Willd.) DC.
Dolichos giganteus Willd.
Gilbert Is.: Tabiteuea (drift seed)

Pueraria DC.

Pueraria lobata (Willd.) Ohwi
Gilbert Is.

Sophora L.

Sophora tomentosa L.
Gilbert Is.: Abemama; Onotoa

Vigna Savi

Vigna marina (Burm.) Merr.
Phaseolus marinus Burm.
Dolichos luteus Sw.
Vigna lutea (Sw.) A. Gray
Canavalia obtusifolia sensu Guillaumin non DC.
Gilbert Is.: Butaritari; Tarawa

*Vigna unguiculata ssp. sesquipedalis (L.) Verdc.
Dolichos sesquipedalis L.
Gilbert Is.: Kuilimati; Nikunan; Nonanti

OXALIDACEAE

Oxalis L.

Oxalis corniculata L.
Gilbert Is.

ZYGOPHYLLACEAE

Tribulus L.

Tribulus cistoides L.
Gilbert Is.

RUTACEAE

Citrus L.

*Citrus aurantiifolia (Christm.) Swingle
Limonia aurantifolia Christm.
Citrus medica sensu Catala, Guillaumin, non L.
Gilbert Is.: Butaritari

*Citrus limon (L.) Burm. f.
Citrus medica var. limon L.
Gilbert Is.

SURIANACEAE

Suriana L.

Suriana maritima L.
Gilbert Is.: Tabiteuea; Onotoa

POLYGALACEAE

Polygala L.

*Polygala paniculata L.
Gilbert Is.: Tarawa

EUPHORBIACEAE

Acalypha L.

Acalypha amentacea var. grandis (Benth.) Fosb.
Acalypha grandis. Benth.
Gilbert Is.

*Acalypha amentacea ssp. wilkesiana (Muell.-Arg.) Fosb. f. wilkesiana
Acalypha wilkesiana Muell.-Arg.
Acalypha grandis sensu auct. Micr. non Benth.
Gilbert Is.: Abaiang; Tarawa; Tabiteuea

*Acalypha amentacea ssp. wilkesiana f. circinata (Muell.-Arg.) Fosb.
Gilbert Is.: Tarawa

Acalypha amentacea vars.
Gilbert Is.: Butaritari, Abaiang, Tarawa; Beru,

*Acalypha hispida Burm. f.
Gilbert Is.: Abaiang

Codiaeum Bl.

Codiaeum variegatum (L.) Bl.
Gilbert Is.

Euphorbia chamissonis (Kl. & Gke.) Boiss.
Anisophyllum chamissonis Kl. & Gke.
Euphorbia atoto sensu auct. Micr. non Forst. f.

Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Onotoa; Beru

*Euphorbia cyathophora Murr.
Euphorbia heterophylla sensu auct. non L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Abirang; Marakei

Euphorbia geniculata Ortega
Gilbert Is.

*Euphorbia glomerifera (Millsp.) Wheeler
Chamaesycie glomerifera Millsp.
Euphorbia hyisopifolia sensu auct. non L.
Gilbert Is.: Butaritari; Tarawa

Euphorbia heterophylla L.
Gilbert Is.

*Euphorbia hirta L.
Euphorbia pilulifera L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea

*Euphorbia prostrata Ait.
Euphorbia chamaescyce sensu auct. non L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Abaiang; Marakei; Onotoa

*Euphorbra rubricunda Steud.
Euphorbia thymifolia L. auct. non L.
Gilbert Is.: Tarawa

Macaranga Thou.

Macaranga carolinensis Volk.
Gilbert Is.: Tarawa

*Manihot L.

*Manihot esculenta Crantz
Manihot utilissima Pohl
Manihot utilissima var. aipi Pohl
Jatropha manihot L.
Gilbert Is.

Pedilanthus Neck. ex Poit.

*Pedilanthus tithymaloides (L.) Poit.
Euphorbia tithymaloides L.
Gilbert Is.: Tarawa

Phyllanthus L.

*Phyllanthus amarus Sch. & Th.
Phyllanthus niruri sensu auct. plur. non L.
Phyllanthus simplex sensu Guillaumin non Retz.
Gilbert Is.: Buratitari; Tarawa; Nonauti; Tabiteuea; Onotoa

*Ricinus L.

*Ricinus communis L.
Gilbert Is.: Butaritari; Tarawa

ANACARDIACEAE

Mangafera L.

Mangifera indica L.
Gilbert Is.: Butaritari; Tarawa; onotoa

SAPINDACEAE

Allophylus L.

Allophylus timoriensis (DC.) Bl.
Schmidelia timoriensis DC.
Allophylus cobbe sensu auct. Micr. non (L.) Bl.
Allophylus litoralis Bl.
Allophylus laetus Radlk.
Schmidelia litoralis Bl.
Gilbert Is.: Butaritari

Dodonaea L.

Dodonaea viscosa (L.) Jacq.
Ptelea viscosa L.
Dodonaea viscosa f. repanda (Schum. & Thonn.) Radlk.
Gilbert Is.: Tarawa; Nonouti; Onotoa; Abemama

TILIACEAE

Triumfetta L.

Triumfetta procumbens Forst. f.
Triumfetta fabreana Gaud.
Gilbert Is.: Butaritari; Marakei; Tarawa; Nonouti; Tabiteuea; Onotoa;

MALVACEAE

Abutilon L.

Abutilon asiaticum var. albescens (Miq.) Fosb.
Abutilon albescens Miq.
Gilbert Is.: Tarawa

Abutilon indicum (L.) Sweet
Sida indica L.
Sida maura Link ex Endl. (error for S. mauritiana Link?)
Gilbert Is.: Tarawa

Gossypium L.

Gossypium arboreum L.

Gilbert Is. (probably a misdet. of G. hirsutum)

Gossypium barbadense
Gilbert Is.

Hibiscus L.

*Hibiscus manihot L.
Abelmoscgus manihot (L.) Moench.
Gilbert Is.

*Hibiscus rosa-sinensis L. var. rosa-sinensis
Gilbert Is.: Tarawa

Hibiscus tiliaceus L.
Pariti tiliaceus (L.) A. St. Hil.
Gilbert Is.: Tarawa; Onotoa; Beru

*Hibiscus ornamental hybrids
Gilbert Is.: Tabiteuea

Sida L.

Sida fallax Walp.
Sida meyeniana sensu auct. Micr. possibly non Walp.
Gilbert Is.: Butaritari; Marakei; Beru; Tarawa; Tabiteuea; Onotoa

Sida rhombifolia L.
Gilbert Is.: Butaritari

Thespesia Sol. ex correa

Thespesia populena (L.) Sol. ex Correa
Hibiscus populneus L. (at least in part)
Gilbert Is.: Butaritari; Tabiteuea

STERCULIACEAE

Melochia L.

*Melochia odorata L f.
Gilbert Is.: Tarawa

GUTTIFERAE

Calophyllum L.

Calophyllum inophyllum L.
Gilbert Is.: Butaritari; Tarawa; Maiana; Nonouti; Tabiteuea; Onotoa

PASSIFLORACEAE

*Passiflora L.

*Passiflora edulis Sims

Gilbert Is.: Tarawa

*Passiflora foetida var. gossypifolia (Desv.) Mart.
Gilbert Is.: Butaritari

*Passiflora foetida var. hispida (DC.) Killip
Gilbert Is.: Tarawa

*CARICACEAE

*Carica L.

*Carica papaya L.
Gilbert Is.: Tarawa; Abemama; Nonouti; Onotoa

CUCURBITACEAE

*Citrullus Schrad.

*Citrullus lanatus var. caffrorum (Alef.) Fosberg
Citrullus vulgaris var. caffrorum Alef.
Citrullus vulgaris Schrad. ex Eckl. & Zeyh.
Gilbert Is.

*Cucumis L.

*Cucumis melo L.
Gilbert Is.: Tarawa

*Cucumis melo var. reticulatus Ser.
Gilbert Is.

*Cucurbita L.

*Cucurbita pepo L.
Gilbert Is.: Tarawa

LYTHRACEAE

Pemphis Forst.

Pemphis acidula Forst.
Lythrum pemphis L. f.
Gilbert Is.: Butaritari; Tarawa; Aranuka; Nonouti; Tabituea; Onotoa

RHIZOPHORACEAE

Bruguiera Lam.

Bruguiera gymnorhiza (L.) Lam.
Rhizophora gymnorhiza L.
Rhizophora conjugata L.
Bruguiera conjugata (L.) Merr.
Gilbert Is.: Butaritari; Abemama; Tabiteuea

Rhizophora mucronata Lam. var stylosa (Griff.) Schimper
Rhizophora stylosa Griff
Gilbert Is.: Butaritari; Tarawa; Aranuka; Abaiang; Nonouti; Onotoa

SONNERATIACEAE

Sonneratia L. f.

Sonneratia alba J. E. Sm.
Sonneratia acida sensu auct. Micr. non L. f.
Sonneratia caseolaris sensu auct. Micr. non (L.) Engl.
Gilbert Is.: Butaritari; Marakei

COMBRETACEAE

Lumnitzera Willd.

Lumnitzera littorea (Jack) Voigt
Pyrrhanthus littoreus Jack
Lumnitzera coccinea (Gaud.) W. & A.
Gilbert Is.: Butaritari; Tarawa

Terminalia L.

*Terminalia catappa L.
Terminalia moluccana sensu auct. non Lam.
Gilbert Is.: Tarawa; Nonouti

Terminalia samoensis Rech.
Terminalia litoralis sensu auct. non Seem.
Gilbert Is.: Butaritari; Tarawa; Nonouti; Onotoa

LECYTHIDACEAE

Barringtonia Forst.
Butonica Lam.

Barringtonia asiatica (L.) Kurz
Mammea asiatica L.
Barringtonia speciosa Forst.
Barringtonia butonica Forst.
Gilbert Is.: Makin; Butaritari; Tarawa; Onotoa

MYRTACEAE

Psidium L.

*Psidium guajava L.
Gilbert Is.

ONAGRACEAE

Ludwigia L.

Ludwigia octovalvis (Jacq.) Raven
Oenothera octovalvis Jacq.
Jussiaea suffruticosa L. non Ludwigia suffruticosa Walt.
Jussiaea suffruticosa var. ligustrifolia (HBK.) Griseb.
Gilbert Is.: Butaritari; Tarawa; Onotoa

ARALIACEAE

Polyscias Forst.

*Polyscia filicifolia (Moore) Bailey
Gilbert Is.: Tarawa

*Polyscias fruticosa (L.) Harms
Panax fruticosus L.
Nothopanax fruticosus (L.) Miq.
Gilbert Is.: Abaiang

Polyscias grandifolia Volkens
Gilbert Is.

*Polyscias guilfoylei (Cogn. & March.) Bailey
Aralia guilfoylei Cogn. & March.
Nothopanax guilfoylei (Cogn. & March.) Merr.
Gilbert Is.: Tarawa; Tabiteuea; Onotoa

*Polyscias scutillaria (Burm. f.) Fosb.
Gilbert Is.

UMBELLIFERAE

Apium L.

*Apium petroselinum L.
Petroselinum crispum (Mill.) Mansf.
Gilbert Is.

OLEACEAE

Jasminum L.

*Jasminum sambac (L.) Ait.
Nyctanthes sambac L.
Gilbert Is.: Tarawa

GENTIANACEAE

Fagraea Thunb.

Fagraea berteriana Gray ex Benth. var.?
Gilbert Is.

APOCYNACEAE

*Allamanda L.

*Allamanda hendersonii Bull
Allamanda cathartica var. hendersonii (Bull) Bailey & Raff.
Gilbert Is.: Tarawa

*Catharanthus G. Don
Lochnera Reichenb
Vinca sensu auct., L. pro parte, non typ.

*Catharanthus roseus (L.) G. Don
Vinca rosea L.
Lochnera rosea (L.) Reichenb.
Gilbert Is.: Tarawa; Nonouti; Tabiteauea; Onotoa

Cerbera L.

Cerbera manghas L.
Gilbert Is.

Neisosperma Raf.
Ochrosia Juss. pro parte non typ.
Gilbert Is.: Tarawa; Nonouti

Neisosperma oppositifolia (Lam.) Fosb. & Sachet
Ochrosia oppositifolia Lam.
Gilbert Is.

*Nerium L.

*Nerium oleander L. var. oleander
Gilbert Is.: Tarawa

*Nerium oleander var. indicum (Mill.) Der. & Deg.
Gilbert Is.

*Plumeria L.

*Plumeria obtusa L.
Gilbert Is.

*Plumeria rubra L.
Plumeria acuminata Ait.
Gilbert Is.

ASCLEPIADACEAE

Asclepias L.

*Asclepias curassavica L.
Gilbert Is.: Tarawa

*Calotropis L.

*Calotropis gigantea (L.) R. Br.
Asclepias gigantea L.

Gilbert Is.: Tarawa

CONVOLVULACEAE

Ipomoea L.

*Ipomoea aquatica Forsk.
Ipomoea reptans sensu Merr., Kaneh. non (L.) Poir.
Gilbert Is.: Tarawa

*Ipomoea batatas (L.) Lam.
Convolvulus batatas L.
Gilbert Is.: Tarawa

Ipomoea littoralis Bl.
Ipomoea denticulata (Desv.) Choisy
Convolvulus denticulatus Desv.
Ipomoea gracilis sensu auct. non R. Br.
Gilbert Is.: Butaritari

Ipomoea macrantha R. & S.
Convolvulus tuba Schlecht.
Ipomoea tuba (Schlecht.) G. Don
Ipomoea glaberrima Boj. ex Bouton
Ipomoea bona-nox sensu Guillaumin non L.
Gilbert Is.: Tarawa; Nonouti; Tabiteuea; Onotoa

Ipomoea pes-caprae ssp. brasiliensis (L.) v. Ooststr.
Ipomoea brasiliensis (L.) Sweet
Gilbert Is.: Butaritari; Tarawa

BORAGINACEAE (EHRETIACEAE)

Cordia L.

Cordia sebestena L. Pickering's Gilbert records see Cordia subcordata Lam.

Cordia subcordata Lam
Gilbert Is.: Butaritari; Tarawa; Abemama; Nonouti

Tournefortia L.

Tournefortia angentea L. f.
Tournefortia sericea Cham.
Messerschmestia argentea (L.F.) Jtn.
Gilbert Is.: Butaritari; Tarawa; Nonouti; Tabiteuea; Onotoa

VERBENACEAE

Clerodendrum L.

Clerodendrum inerme var. oceanicum A. Gray
Volkameria inermis L.
Clerodendrum nereifolium Wall.
Clerodendrum commersonii (Poir.) Spreng.

Gilbert Is.: Butaritari; Tarawa; Nonouti; Tabiteuea; Onotoa

*Lantana L.

*Lantana camara var. aculeata (L.) Mold.
Lantana aculeata L.
Gilbert Is.: Butaritari; Nonouti

*Lantana camara L. var. camara
Gilbert Is.: Tarawa

Premna L.

Premna serratifolia L.
Premna obtusifolia R. Br.
Premna integrifolia L.
Premna tahitensis Schauer
Premna alba Lam
Premna angustiflora Lam
Premna paulobarbata Lam
Premna timoriana sensu Lam, perhaps non Decne.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Onotoa

Premna timoriana Decne. see Premna serratifolia L. at least for Gilbert Islands record.

Stachytarpheta Vahl

*Stachytarpheta jamaicensis (L.) Vahl
Verbena jamaicensis L.
Stachytarpheta dichotoma sensu auct. non (HBK.) Vahl
Stachytarpheta indica sensu auct. non (L.) Vahl
Gilbert Is.: Butaritari; Tarawa

*Stachytarpheta urticaefolia Sims
Gilbert Is.: Butaritari; Tarawa

Vitex L.

Vitex negundo var. bicolor (Willd.) Lam
Vitex bicolor Willd. Moldenke
Gilbert Is.: Abaiang

Vitex trifolia L.
Vitex trifolia var. subtrisecta (O. Ktze) Mold.
Gilbert Is.

LABIATAE

*Mentha L.

*Mentha piperita L.
Gilbert Is.

Ocimum L.

*Ocimum basilicum L.
Gilbert Is.: Tarawa; Nonouti; Nikunau; Marakei

Ocium sanctum ?
Gilbert Is.

*Plectranthus L'Herit.

*Plectranthus scutellarioides (L.) R. Br.
Coleus scutellarioides (L.) Benth.
Ocimum scutellarioides L.
Coleus blumei Benth.
Coleus atropenfureus
Gilbert Is.: Tarawa

SOLANACEAE

*Capsicum L.

*Capsicum annuum L. sensu lato (variety not indicated).
Gilbert Is.

*Capsicum annuum var. grossum (L.) Sendtn.
Capsicum grossum L.
Gilbert Is.: Tarawa

*Capsicum annuum var. longum (L.) Sendtn.

*Capsicum frutescens L.
Capsicum baccatum L.
Capsicum frutescens var. baccatum (L.) Irish
Capsicum fruticosum L. (sphalm?)
Gilbert Is.: Tarawa; Tabiteuea

*Datura L.

*Datura metel L.
Datura fastuosa L.
Datura fastuosa var. alba (Nees) C. B. Cl.
Gilbert Is.: Butaritari; Abaiang; Tarawa; Tamana

*Nicotiana L.

*Nicotiana tabacum L.
Gilbert Is.: Tarawa

Physalis L.

*Physalis angulata var. angulata
Physalis minima sensu auct. non L.
Gilbert Is.: Butaritari; Abaiang; Tarawa; Nonouti; Onotoa

*Physalis angulata var. lanceifolia (Nees) Waterfall
Physalis lanceifolia Nees
Gilbert Is.: Onotoa

*Physalis peruviana L.
Physalis edulis sensu Pickering, Luomala non Sims
Gilbert Is.: Butaritari

*Solanum L.

*Solanum lycopersicum L.
Lycopersicon esculentum Mill.
Lycopersicon lycopersicum (L.) Karst.
Gilbert Is.: Tarawa

*Solanum melongena L.
Gilbert Is.

*Solanum torvum Sw.
Gilbert Is.: Tarawa; Abemama

SCROPHULARIACEAE

Angelonia Homb. & Bump.

*Angelonia angustifolia Benth.
Gilbert Is.: Tarawa

*Angelonia salicariaefolia H. & B.
Angelonia gardneri Hook.
Gilbert Is.: Tarawa

Bacopa Aubl.
Herpestis Gaertn. f. pro parte

Bacopa monnieri (L.) Wettst.
Lysimachia mannieri L.
Gratiola monnieri (L.) L.
Herpestis monnieria (L.) HBK.
Gilbert Is.: Butaritari

*Russelia Jacq.

*Russelia equisetiformis Schlecht. & Cham.
Russelia juncea Zucc.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Onotoa

BIGNONIACEAE

*Tecoma Juss.

*Tecoma stans (L.) Juss. ex HBK.
Bignonia stans L.
Stenolobium stans (L.) D. Don
Gilbert Is.: Little Makin; Butaritari; Tarawa

ACANTHACEAE

*Acanthus L.

*Acanthus sp. of Luomala
Gilbert Is.

Asystasia Bl.

*Asystasia gangetica (L.) Anders.
Justicia gangetica L.
Asystasia nemorum Nees
Asystasia coromandeliana Nees
Gilbert Is.: Tarawa, Butaritari

Hemigraphis Nees

Hemigraphis reptans (Forst.) T. Anders,
Ruellia reptans Forst.
Gilbert Is.: Butaritari

*Pseuderanthemum carruthersii var. atropurpureum (Bull) Fosb.
Pseuderanthemum atropurpureum (Bull) Radlk.
Eranthemum atropurpureum Bull
Odontonema nitidum sensu Merr. non (Jacq.) 0. Ktze.
Graptophyllum pictum sensu Guill. non Nees
Eranthemum versicolor Hort.
Gilbert Is.: Tarawa; Marakei; Onotoa

*Pseuderanthemum carrutharsii (Seem.) Guill. var; carruthersii
Graptophyllum pictum sensu Catala non Nees
Gilbert Is.: Abemama; Tarawa; Onotoa, nononti

*Pseuderanthemum laxiflorum (Gray) Hubb.
Pseuderanthemum bicolor sensu auct. non (Schrank.) Radlk.
Gilbert Is.: Tarawa

RUBIACEAE

Aidia Lour.
Gilbert Is.

*Gardenia taitense DC.
Gilbert Is.

Guettarda L.
Guettarda speciosa L.
Gilbert Is.: Butaritari; Tarawa; Aranuka; Tabiteuea; Nonouti; Abaiang; Onotoa Marakei, Abaiang

Hedyotis biflora (L.) Lam.
Oldenlandia biflora L.
Gilbert Is.: Butaritari

Hedyotis verticillata (L.) Lam.
Gilbert Is.: Butaritari

Ixora L.

Ixora casei Hance
Ixora macrothyrsa sensu auct. plur. non (Teysm. & Binn.) T. Moore
Ixora javanica sensu auct. non (Bl.) DC.
Gilbert Is.: Tarawa, Abaing, Butaritari

*Ixora coccinea L.
Ixora fraseri Hort. ex Gent.
Gilbert Is.: Tarawa

Morinda L.

Morinda citrifolia L.
Morinda indica L.
Gilbert Is.: Butaritari; Tarawa; Nonouti; Tabiteuea; Onotoa

Pentas Benth.

*Pentas lanceolata (Forsk.) DeFlers
Ophiorrhiza lanceolata Forsk.
Gilbert Is.: Tarawa

Spermacoce L.

*Spermacoce assurgens R. & P.
Spermacoce suffrutescens Jacq.
Borreria laevis sensu auct. plur. non Lam.
Gilbert Is.: Butaritari; Tarawa

GOODENIACEAE

Scaevola L.
Lobelia sensu Adanson non L.

Scaevola sericea Vahl
Lobelia taccada Gaertn.
Scaevola lobelia Murr.
Scaevola sericea Forst. f. (nom. nud.)
Scaevola taccada (Gaertn.) Roxb.
Scaevola koenigii Vahl
Scaevola frutescens sensu auct. non (Mill.) Krause
Scaevola frutescens var. sericea (Forst. f.) Merr. (nom. nud.)
Gilbert Is.: Butaritari, Nonouti, Tetua, Tarawa, Marakei, Abaiana

COMPOSITAE

Adenostemma Forst.

Adenostemma lanceolatum Miq.
Adenostemma lavenia sensu auct. Micr. non (L.) 0. Ktze.
Adenostemma viscosum sensu auct. Micr. non Forst.
Gilbert Is.?

*Aster L.

*Aster laevis L.
Gilbert Is.: Tarawa

Bidens L.

*Bidens pilosa L. var. pilosa
Gilbert Is.: Butaritari

Cichorium L.

*Cichorium endivia var. latifolia Chev.
Gilbert Is.

*Cichorium endivia var. crispa (Mill.) Chev.
Cichorium crispum Mill.
Gilbert Is.

*Conyza Less.
Erigeron L. pro min. parte

*Conyza bonariensis (L.) Cronq.
Erigeron bonariensis L.
Erigeron crispus Pourr.
Gilbert Is.: Butaritari; Tarawa

*Gaillardia Foug.

*Gaillardia pulchella Foug.
Gaillardia lanceolata sensu Bryan non Michx.
Gilbert Is.: Tarawa

Pluchea Cass.

Pluchea carolinensis (Jacq.) G. Don see Pluchea symphytifolia (Mill.) Gillis

*Pluchea × fosbergii Coop. & Gal
Gilbert Is.: Butaritari

*Pluchea indica (L.) Less.
Baccharis indica L.
Pluchea purpurascens sensu Guillaumin non DC.
Gilbert Is.: Butaritari

Pluchea symphytifolia (Mill.) Gillis
Conyza symphytifolia Mill.
Pluchea carolinensis (Jacq.) G. Don
Pluchea odorata auct. plur. non (L.) Cass.
Gilbert Is.: Butaritari; Tarawa

Sigesbeckia L.

Sigesbeckia orientalis L.
Gilbert Is.: Tarawa

Synedrella Gaertn.

*Synedrella nodiflora (L.) Gaertn.
Verbesina nodiflora L.
Gilbert Is.: Butaritari; Tarawa

Tridax L.

*Tridax procumbens L.
Gilbert Is.: Butaritari; Tarawa

Vernonia Schreb.

Vernonia cinerea (L.) Less. sensu lato
Conyza cinerea L.
Gilbert Is.: Butaritari; Tarawa; Tabiteuea; Onotoa

Wollastonia DC.

Wollastonia biflora (L.) DC.
Wedelia biflora (L.) DC.
Gilbert Is.: Abaiang

Zinnia L.

Zinnia elegans Jacq.
Gilbert Is.

Zinnia pauciflora
Gilbert Is.

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PLANTS OF KIRIBATI: A LISTING AND ANALYSIS OF VERNACULAR NAMES

BY

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PLANTS OF KIRIBATI:

A LISTING AND ANALYSIS OF VERNACULAR NAMES

By

R.R. THAMAN*

INTRODUCTION

This paper attempts to provide a comprehensive listing and analysis of Kiribati plant names, along with the corresponding Latin, English, and selected Pacific-island vernacular names for plant species with recognized Kiribati vernacular names. The study focuses on those species found on the 16 islands of the Kiribati group proper (known traditionally as Tungaru), with no attempt being made to include species which might be present on the other islands of Kiribati: Banaba (Ocean Island) to the west and the Line and Phoenix Islands to the east. A brief analysis of relevant past studies and the nature of the plants and their names is also included. The paper is based on a ten-day in-the-field inventory of Kiribati plant names and plant resources on the islands of Abemama and Tarawa in 1984, plus a four-week field study of the plants of Nauru in 1980-81, which included a study of the plants of the resident I Kiribati contract worker community. The findings of these studies were then emended in light of comparison and cross-checking with plant lists and plant names from pre-existing sources.

VALUE OF PLANT LISTS

Among the most valuable tools of botanists wishing to conduct field studies in a given locality would be a list of the Latin, or botanical, names of plants found there. Perhaps even more useful to the non-botanist, who is unfamiliar with botanical names, would be lists of local or indigenous vernacular names along with the corresponding Latin and common names. Such lists, can be arranged in alphabetical order by the local names, or with the local and botanical names indexed alphabetically.

Although indigenous peoples have little or no knowledge of the English and other common names of local plants, and virtually no knowledge of Latin binomials, they do have considerable, often immense knowledge of the local names, ecology, and cultural uses of their flora. Such knowledge is particulary common amongst older people in rural areas and constitutes an enormous often "dying" cultural and scientific resource, which if compiled in lists, and analyzed, could be of immense value to a wide range of users.

Highly trained botanists, for example, who wish to use local names to have local informants/assistants help them locate and collect given species or to survey and describe the species composition of given vegetation associations would find such lists invaluable. Ethnobotanists, anthropologists, plant geographers, ecologists, agricultural scientists and others untrained in systematic botany and plant taxonomy would find such lists almost a necessity, unless they can afford the countless hours and cost required to collect, preserve, and prepare herbarium specimens of unknown species for forwarding to a reputable plant taxonomist or herbarium. Plant lists, from a range of different island groups or related languages groups, would be particularly useful to linguistic anthropologists interested in glottochronology and prehistorians interested in Pacific island settlement chronologies. Government research organizations, planning agencies and overseas consultants and aid

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missions would also find such lists of considerable value, as would tourists and other persons interested in the local flora and environment.

Lists of local plant names are also of considerable value as teaching resources to science, social science and even English or language teachers who wish to involve ther students in fieldwork or to focus their lessons on the local environment or culture, rather than on in-the-classroom textbook(usually from overseas) learning. The predominant emphasis on "white-collar western education has in effect often divorced students from a considerable body of their local language and their traditional cultural ecology. Although most "urbanized" island students often remain fluent in their mother tongue, many do not know the local names for the countless plants and animals that have mothered their cultures for millennia.

PREVIOUS STUDIES AND SOURCE MATERIALS

The most complete and detailed published materials on Kiribati plant names, which also include Latin and common names and descriptive material are: 1) Luomala's Ethnobotany of the Gilbert Islands (1953) published by the Bernice P. Bishop Museum; 2) Rene Catala's Report on the Gilbert Islands: Some Aspects of Human Ecology (1956), resulting from an ecological research project jointly supported by the Office de Scientifique and Technique d'Outre Mer (ORSTOM) and the South Pacific Commission (SPC), and published in the Atoll Research Bulletin, and 3) a limited issue (30 copies) typed publication, Some Plants of Kiribati: An Illustrated List (1982), with original colour photographs of individual plant species, by Overy, Polunin and Wimblett, and produced and distributed by the National Library and Archives, Tarawa.

Also of considerable value are the 426-page Gilbertese-English Dictionary (Te Tekitinari n Taetae ni Kiribati ma n Ingiriti), a translation by Sister Mary Oliva of a "Gilbertese-French Dictionary" compiled by Catholic priest Father E. Sabatier over a forty year period in collaboration with Father C. Ramuz(Sabatier and Oliva, 1971), and A Gilbertese-English Dictionary compiled by Reverend Hiram Bingham Jr. of the London Missionary Society in 1908(republished by the American Board of Commissioners for Foreign Missions in 1953).

Other sources on Kiribati plant names include a typed list of 93 Kiribati plant names compiled in 1946 by an I Kiribati (indigenous inhabitant of Kiribati), Bauro Ratieta, and sent to the Bishop Museum in Honolulu by H.E. Maude, then Resident Commissioner of the Gilbert and Ellice Islands Colony, and two collections of herbarium specimens, some with names, held by the Agricultural Division and The University of the South Pacific(USP) Atoll Research Unit(ARU) on Tarawa.

The main sources for correct Latin names, the presence or absence of given species and whether they are indigenous include: 1) Fosberg, Sachet and Oliver's "A Geographical Checklist of Micronesian Dicotyledonae" (1979), and "Geographical Checklist of Micronesian Pteridophyta and Gymnosperms" (1982), both published in Micronesica; 2) Fosberg and Sachet's "Gilbert Island Flora, Checklist" (1987); 3) Fosberg and Sachet's other publications on the flora of Micronesia; and 4) the works by Luomala (1953), Catala (1957), and Overy, Polunin and Wimblett (1982).

Other sources of interest include: 1) the Narrative of the United States Exploring Expedition (Wilkes, 1845) and reports by the expedition's naturalist Charles Pickering (1876); a list of 23 plants prepared in 1884, eleven years after a visit to Kiribati, by a British official; and various smaller lists or mentions of species in accounts by other visitors to Kiribati (Luomala, 1953). Other studies which provide cross references include Moul's (1957) report "Some Aspects of the Flora of Onotoa Atoll, Gilbert Islands", Christophersen's (1927) Vegetation of Pacific Equatorial Islands, and Wester's "Checklist of the Vascular Plants of the Northern Line Islands", which although focusing on the Line

Islands of Kiribati, do give some information on the plants which are found in the atoll environment of the main Tungaru group. Small's (1972) book on Atoll Agriculture in the Gilbert and Ellice Islands also contains valuable lists of Latin and Kiribati names of useful cultivated and wild plants as well as weed species.

The most comprehensive of these previous studies is Luomala's who reviewed the available published and unpublished literature and previous plant lists, and conducted in-depth studies and collected 56 plant specimens on the island of Tabiteuea. The publication includes a 72-page list of Kiribati plant names, Latin names(when available), and extensive notes on what other sources had to say about each species, cultivar or name (Luomala, 1953: 50-121), as well as an analysis of previous studies and other aspects of Kiribati ethnobotany. The usefulness of her study is limited by the narrow geographical scope of the field study(Tabiteuea only) and the limited number of plant specimens collected.

Catala's (1956) study, although focusing on the more general aspects of human ecology and including sections on climate, soils, natural and cultural vegetation, marine resources, domestic animals, diet, handicrafts and cooperative societies, also includes in-depth notes on important cultivated plants, lists of plants used for food, construction and handicraft, drugs and medicines, ornamentation, compost, fibre, dyes and tanning agents, scenting coconut oil, and livestock feed, and a description of the vegetation and flora, which includes a 30-page list of plant species, most of which were basd on herbarium identification of specimens. Common and Kiribati names were provided when available.

The study by Overy, Polunin and Wimblett (1982) consists of descriptions, photos and, when available, Latin, English and Kiribati names for 145 plant species. Their analysis and aquisition of Kiribati names took advantage of previous works by Luomala (1953), Catala (1956), and Small (1972), as well as the dictionaries of Bingham and Sabatier, a number of unpublished works on Kiribati plants ethnobotany, medicinal plants, and plant names which were available in government departments and the National Library and Archives in Tarawa, plus the considerable local experience of Overy and Wimblett who have worked in Kiribati for many years with the National Library and Archives and Agricultural Division, respectively, and Dr Polunin who conducted an investigation of Kiribati medicinal plants for the World Health Organization (WHO).

The dictionaries compiled by Bingham and Oliva (1953) during the first decade of this century and by Sabatier (1971) over a forty year period up until the mid-1950s constitute rich sources and cross-checks on Kiribati plant names. Unfortunately Bingham's includes only three Latin names (Luomala, 1953:40) and, although many Latin binomials are provided along with Kiribati names by Sabatier, many are either incorrect, or, which is more often the case, misspelled (possibly due to lack of knowledge by the translator or to undetected typographical errors).

CURRENT STUDY

The present study is based on an in-depth study of available literature plus a ten-day intensive field study with I Kiribati informants on Abemama and North and South Tarawa, in August 1984. During this period the Latin and Kiribati names of all plant species found in urban and rural areas were recorded and listed alphabetically. These lists were then cross-checked, consolidated, emended, and augmented, both during and after the field study, using lists and names from previous studies. The Kiribati fieldwork was also augmented by findings from a four-week 1980-81 study in Nauru of the plants cultivated by I Kiribati contract workers in home gardens and food gardens and of the local plant names and species composition of Nauru's natural and cultural vegetation (Thaman, 1985; Thaman, et al. 1985; Manner, et al. 1984, 1985).

KIRIBATI PLANT NAMES

Table 1 shows the number of Kiribati plant names with no corresponding Latin name and the number of Kiribati names plus the corresponding Latin binomial(botanical identification) available from each of the four major published sources. These were augmented by other sources which provided some Kiribati names and their Latin or botanical names and which indicated the presence or absence of species, and were cross-checked with other plant listings, particularly Fosberg and Sachet (1979 and 1982) and St. John, 1973), to yeild the "Total" figures.

Of the just over 290 distinct vascular plant species reportedly present at some time in the main or Tungaru group of Kiribati, approximately 183, just under two-thirds seem to have local vernacular names. A listing of 110 species reportedly present at some time, but which seem to have no recognized Kiribati name can be found in the Appendix. Table 3 is the major list, in Kiribati alphabetical order(explained below) for those species which seem to have recognized vernacular names.

In addition to the 183 named species there were an additional eleven varieties, forms, subspecies or hybrids which were referred to by the same names, e.g. te aronga for all Acalypha amentacea subspecies and forms, te orion, te bero, and te keibu for both botanical varieties of Nerium oleander, Ficus tinctoria, and Crinum asiaticum, respectively. Similarly , Te mai, te Kabiti n Tiana, te riti and te roti for Artocarpus alitilis x mariannenses, Brassica, Canna, and Hibiscus hybrids respectively.

Table 1. Number of vernacular Kiribati plant names and botanical identifications in major published sources and from the 1984 field study, and the total resulting from the consolidation of all studies (Note: the botanical identification of at least 12 species remain uncertain).

	Loumala 1953	Catala 1956	Sabatier 1971	Overy 1982	Thaman 1984	TOTAL
Kiribati Names	111	86	111	108	141	183
Kiribati Names and Botanical Name	69	84	78	104	138	170

Included as distinct "species", even though they are not distinct, are four distinct banana cultivars that were observed to be present in Kiribati. The reason for doing so is that the nomenclature for the genus Musa is confused, with most of the common seedless cultivars or clones being triploid crosses or genomes of the fertile species Musa acuminata Colla and M. balbisiana Colla, and not true species. The Latin binomials Musa sapientum L. and M. paradisiaca L. ssp. sapientum are commonly for the the taller bananas, which are generally eaten ripe, but which are also cooked throughout the Pacific as starchy staples, and M. paradisiaca for the starchier bananas or plantains, which are usually eaten cooked a a staple starch, but occasionally eaten as ripe fruit. The nomenclature most widely used by agronomists is the "genome nomenclature"developed by Simmonds, which classifies all cultivars or

clones on the basis of their assumed genetic background, eg. Musa ABB Group would be a triploid cross of one M. acuminata group and two M. balbisiana groups(Purseglove, 1975:343-355; Firman, 1972). Both nomenclature systems are presented, when available, to more precisely identify the clones that are currently present in Kiribati.

Among the 183 distinct species, the same Kiribati name is commonly applied to similar species. For example te bingibing applies to both native species Thespesia populnea and probably Hernandia nymphaeaefolia and te boi to the indigenous species Portulaca lutea and Sesuvium portalucastrum, as well as to the exotic P. oleracea.

Te kaura applies to Sida fallax, as well as to Abutilon indicum (= A. asiaticum var. albescena for Gilbert Island records) and Wollastonia biflora, and te keang to the ferns Phymatodes scolopendria and Nephrolepis hirsutula, as well as to the aquatic plant, Thalassa humprichii. Te kitoko applies to both Canavalia cathartica and Vigna marina, and te ruku to the indigenous Ipomoea littoralis, I. macrantha, I. pes-caprae, and, at times, even to the recently introduced food plant I. aquatica. Te tarai is applied to the indigenous Euphorbia chamissonis, as well as to as many as five recently introduced exotic weedy Euphorbia species, whereas te titania refers to at least two Cyperus sedge species; te tongo refers to both Bruguiera gymnorhiza and Rhizophora mucronata, although te buangi, either alone, or as te tongo buangi, is commonly used to differentiate the former, and te wao refers to both Boerhavia repens and B. tetrandra.

Te uteute is the generic name for almost all grasses, which I Kiribati differentiate from sedges, which have distinctive names such as te maunei, te ritanin, te titania, and te mumute. Only three grass species are commonly differentiated by name, these being two native grasses (ed. note- E. Amabilis is doubtfully native. Fimbristylis is a sedge rather than a grass)te uteute n aine (Eragrostis amabilis) and te uteute ni mane (Fimbristylis cymosa) which mean female and male grass, respectively. The sand burr is always referred to by the descriptive term te kateketeke(thorn), and Luomala reports that Eleusine indica is sometimes referred to as te uteute na banabana(hollow grass). The other grasses, including at least three apparently indigenous species Digitaria setigera, Lepturus repens, Paspalum distichum, Stenotaphrum micranthum, and Thuarea involuta are referred to merely as te uteute.

Among the decorative or ornamental species, te akanta, te iaro, and te meria are applied to all species of the ornamentals Bougainvillea, Pseudoeranthemum, and Plumeria, te marou to both Ocimum sanctum and O. basilicum, and possibly to the indigenous Suriana maritima, te bam(palm) to both Prichardia pacifica and Cycas circinalis, and te roti(rose) to ornamental Hibiscus species, as well as to Zephyranthes rosea and the true roses (Rosa spp.)

Te mai applies as a generic term to all breadfruit, te banana to all Musa clones, te taroro to both Colocasia and Xanthosoma taro species, te beneka to chilli peppers, te kabiti n Tiana to all non-heading Brassica cabbages, te anian to both Allium species, te meren to all melons, te bin(bean) to all bean species plus two edible Physalis species, and te biku to both the edible fig (Ficus carica) and the edible weedy species Passiflora foetida.

Among weedy plants, te uti(head lice) applies to both Stachytarpheta urticaefolia and . jamaicensis and te mota to both Amaranthus dubius and A. viridis.

If some 52 duplicated multispecies names are subtracted from the total of 183 named species, the total of distinct vernacular Kiribati plant names for distinct species becomes 131. If some 16 synonyms (double-listed and/or designated by an asterisk * in Table 3) are considered, the total number of distinct names (but not distinct named species) becomes 147. For example, synonyms such as te baukin, te bamakin and te bangke and te baukin, te bamakin, and te bangke and te babaia and te mwemweara refer to pumpkin (Cucurbita pepo) and papaya (Carica papaya) respectively.

Of the 183 plants with Kiribati names, just over one-third (66) are probably indigenous, eight are presumably aboriginal, pre-European contact introductions, and 105(57 per cent) being exotic "recent"(post- European contact) introductions. Te kaina (Pandanus tectorius) is considered to be both indigenous and of aboriginal introduction(given the diversity of local cultivars), and four species, te ibi (Inocarpus fagifer), te kiriawa (Ficus prolixa?), te mai rekereke (Artocarpus heterophyllus), and te barariku (Dioclea reflexa), are possibly either extinct or only existed in legends(in the case of the first two) or as names for driftseeds(in the case of the latter).

The indigenous species include: 22 tree species, four of which belong to mangrove associations, whereas the balance are widespread coastal strand species, including Pandanus, which is both indigenous and an aboriginal introduction; 8 shrubs or sub-shrubs; 7 vines or creepers; 7 forbs (non-grass herbs); 12 grasses or sedges; three pteridophytes or fern-like species; two aquatic plants; and three fungi.

The trees include te ango (Premna serratifolia), te aroma(?) (Pipturus argenteus), te itai (Calophyllum inophyllum), te kunikun and te ukin (Terminalia catappa and T. samoensis), te uri (Guettarda speciosa), te nimareburebu or te bingibing (Hernandia nymphaeaefolia), te nimatore (Macaranga carolinensis), te non (Morinda citrifolia), te baireati (Barringtonia asiatica), te bero (Ficus tinctoria), te bingibing (Thespesia populnea), te buka (Pisonia grandis), te kaitu (Vitex trifolia), te kanawa (Cordia subcordata), te kaina (Pandanus tectorius), te kiaiai (Hibiscus tiliaceus), te reiango (Cerbera manghas), and te ren (Tournefortia argentea); and the mangrove species, te aitoa (Lumitzera littorea), te tongo (Rhizophora mucronata), te tongo buangui (Bruguiera gymnorhiza), and te nikabubuti (Sonneratia alba)

Shrubby or sub-shrubby species include te aroa (Suriana maritima) te mao (Scaevola sericea), te nikamatutu (Sophora tomentosa), te ngea (Pemphis acidula), te kaiboia (Dodonea viscosa), te kaura (Sida fallax), and te tarai (Euphorbia chamissonis). Vines or creepers include te maukinikin (Tribulus cistoides), te ntanini (Cassytha filiformis), Canavalia cathartica and Vigna marina (both te kitoko), and Ipomoea littoralis, I. macrantha, and I. pes-caprae (all referred to as te ruku).

Indigenous herbaceous species include te ukeuke (Laportia ruderalis), te mtea (Portulaca australis), Portulaca lutea and Sesuvium portulacastrum (both te boi), te kiaou (Triumfetta procumbens), and Boerhavia repens and B. tetrandra (both known as te wao); the grasses te uteute n aine (Eragrostis amabilis), te uteute ni mane (Fimbristylis cymosa)(ed. note- a sedge, not a grass), and Lepturus repens, Thuarea involuta, and the possibly indigenous Digitaria setigera, Paspalum distichum, and Stenotaphrum micranthum, all known simply as te uteute; and the sedges, Cyperus laevigatus and Eleocharis geniculata (both te maunei), te ritanin (Cyperus javanicus), and the possibly indigenous Cyperus odoratus and C polystachyos(both te titania).

The three pteridophyte (fern or fern-like) species are te kimarawa (Psilotum nudum), te keang ni Makin (Polypodium scolopendria), and te keang (Nephrolepis hirsutula); the two named aquatic species, te bukare (Ruppia maritima) and te keang (Thalassa hemprichii); and the three tentatively identified fungi, Polypous sanguinensis, Earliella corrugata, and Myomycetes, all known as te taninganiba. There are presumably other aquatic plants, algae, mosses, fungi, and other non-vascular plants which have recognized Kiribati names, but which have not yet been documented.

The eight aboriginal introductions(not including Pandanus) are all food plants. In addition to edible cultivars of te kaina (Pandanus tectorius), for which there are reportedly nearly 200 Kiribati names, although many are undoubtedly local synonyms for the same cultivars on different islands(Luomala, 1953:16; Catala, 1956:50), the aboriginal introductions include the other major staple food crops, te ni or coconut (Cocos nucifera), te babai or giant swamp taro (Cyrtosperma

chamissonis), and two breadfruit species, both te mai (Artocarpus altilis and A. mariannensis, plus a hybrid of the two). These crops also have a diversity of named cultivars. The balance of the aboriginal introductions includes the formerly more important te makemake or Polynesian arrowroot [Tacca], now primarily an adventive famine food plant. the occasionally cultivated te taororo or taro (Colocasia esculenta), te iam or yam (Dioscorea spp.), which although having a "Kiribatized" name derived from the English name, was reportedly possibly present at the time of European contact(Luomala, 1953:75), and te kabe, now almost exclusively planted as an ornamental, but almost certainly introduced into the group in pre-contact times, as it is a supplementary food crop in other atoll groups and in other areas of Micronesia and in both western and eastern Polynesia (Thaman, 1984; Barrau, 1961).

In terms of the derivation of "proper" Kiribati plant names, most seem to show greatest affinity to plant names in other Micronesian languages, although, in some cases, there seems to be greater similarity to Polynesian cognates, probably due to the proximity of Kiribati to Tuvalu. For example, te kaura and ekaura are the Kiribati and Nauruan cognates for both Sida fallax and Abutilon asiaticum; te kiaou and ikiau for Triumfetta procumbens; and te kitoko and erekogo for Canavalia cathartica and Vigna marina. The Kiribati, Nauruan, and Marshallese cognates for Cassytha filiformis are te ntanini, denuwanini, and kanin; and te makemake, damagmag, and mokmok or mokemok for Tacca leontopetaloides. Similarly, the Kiribati alternative name for Hernandia nymphaeaefolia, te bingibing, is essentially the same as the Marshallese pingping.

In terms of those names which are closer to Polynesian cognates, the Kiribati te buka is essentially the same as the widespread Polynesian equivalent puka for Pisonia grandis; te kanawa for Cordia subcordata is similar to the Tuvaluan kanava, the Samoan tauanave, the Tongan puataukanave, and the Fijian nawanawa; and the Kiribati name for breadfruit, te mai, is very close to both the Nauruan deme and the Marshallese mei, me, and ma, as well as to the Tuvaluan and Tongan name mei. Given a more comprehensive comparison of Kiribati plant names with Micronesian, Polynesian, and Melanesian cognates should shed considerable light on prehistoric interrelationships between different island groups and their societies.

Of the 105 post-European contact introductions, 41 are decorative or ornamental plants, many of which provide flowers and leaves for making headbands, leis, and for scenting coconut oil, with the balance consisting of 35 food plants, 23 weedy species, and six other useful plants(Table 3).

Some of the more common and widely used recently introduced ornamentals include te akanta (Bougainvillea spp.), te aoaaua (Mirabilis jalapa), te aronga (Pseuderanthemum), te orion (Nerium oleander vars.), te marou (Ocimum sanctum), te meria (Plumeria spp.), nei karairai (Tecoma stans), te bitati (Jasminum sambac), te bumorimori (Calotropis gigantea), te kaibaun (Russelia equisetiformis), te kaibuaka (Lantana camara), te katiru or te katuru (Ixora casei), te kiebu (Crinum spp.), te roti (Hibiscus rosa-sinensis), te ruru (Hymenocallis littoralis), and te tua (Delonix regia).

Among the food species, the most commonly cultivated are the introduced tree crops te babaia or te mwemweara, the papaya (Carica papaya), banana cultivars(Musa triploid clones), known collectively as te banana, but sometimes differentiated by the names te umuumu, te oraora, and te wae, te biku, the edible fig (Ficus carica), and te raim (Citrus aurantiifolia); the staple food crops te tabioka or cassava (Manihot esculenta) and te kumara, the sweet potato (Ipomoea batatas), with tannia (Xanthosoma sagittifolium), known as te taororo, the same name used for the aborinally introduced Colocasia esculenta, being grown occasionally. Other occasionally cultivated food crops which have Kiribati names include te anian (Allium spp.), te meren or cantaloupe (Cucumis melo var. cantalupensis), nambere (Hibiscus manihot), te baigan or eggplant (Solanum melongena), te bainaboro or pineapple (Ananas comosus), te baukin or pumpkin (Cucurbita pepo), te beneka or chilli pepper (Capsicum spp.), te bin or long beans (Vigna sesquipedalis), te kaisoka or sugarcane

(Saccharum officinarum), te tomato or tomato (Solanum lycopersicon), and a number of Brassicà cabbage species and hybrids which are called te kabiti or te kabiti n Tiaina. The remainder of the rarely cultivated "named" food plants such as sweet basil (Ocimum basilicum)(also a fragrant ornamental) , watermelon (Citrullus lanatus), bell pepper (Capsicum annuum var. grossum), cucumber (Cucumis sativus), corn (Zea mays), and water convolvulus (Ipomoea aquatica), plus fruit trees, such as orange (Citrus sinensis), guava (Psidium guajava), lemon (Citrus limon), and Crateva speciosa have only been cultivated on an experimental basis by individual, often expatriate households, aid agencies, service organizations, mission schools, the the government's Agricultural Division, and all have names that are direct "Kiribatizations" of English or other names. were introduced.

The remaining "named" useful plants include te baubau or cotton (Gossypium barbadense), te kaibaba or bamboo (Bambusa sp.), te kaibake or tobacco (Nicotiana tabacum), te robu (Agave sisalana), and two firewood and timber species te kaiteteu (Leucaena leucocephala) and te katurina (Casuarina eqisetifolia).

Of the 111 species reportedly present at one time or another in Kiribati, but which have no reported Kiribati name, 18 are possibly indigenous, one of possibly aboriginal introduction, and 92 of recent post-European introduction. Of the 18 possibly indigenous species, only two, Allophyllus timoriensis and Neisosperma oppositifolia are large shrubs or trees, the rest being shrubby vines or climbers, small weed-like species, grasses or sedges, or ferns, all of which are uncommon, with some, such as Caesalpinia bonduc and Mucuna gigantea, possibly only becoming temporarily established periodically from driftseeds.

The one possibly aboriginal introduction is turmeric(Curcuma longa), whereas the 92 recently introduced exotics are comprised of 42 decorative or ornamental and 15 food plant species, none of which have become as culturally important or as widely cultivated as those species which have Kiribati names, and 35 weedy species or introduced grasses, almost all of which are either rare or have never really become established. Some these probably do have Kiribati vernacular names, but because of their scarcity, it was not possible to show them to knowledgeable I Kiribati informants. Some, like Curcuma longa, which could be te renga, may, in fact, correspond to the unidentified Kiribati plant names listed by Ratieta (1946) and Luomala (1953), and some of the sedges may possibly be referred to by the same names given to other sedges, te maunei, te ritanin and te titania, and Abutilon asiaticum by the name te kaura, which refers to both Abutilon indicum and Sida fallax. To establish whether this is the case will require that plant specimens be shown to knowledgeable I Kiribati informants.

NATURE AND DERIVATION OF PLANT NAMES

Kiribati vernacular plant names can be classified into four distinct groups: 1) "proper" names which are used almost exclusively for a given plant or plants, rather than being words with other meanings; 2) descriptive names, which refer to characteristics of plants, e.g., "smelly plant", "golden plant", "thorny plant", "shark-plant" or "bad plant"; 3) Kiribati renditions or "Kiribatizations" of non-Kiribati plant names, e.g., te anian, te orion, and te roti for onion, oleander, and rose; and 4) names which refer to the origin of an introduced plant or which are named after the person responsible for its introduction, e.g., te ruru ni Buranti (the lily from France) or neikarairai (Miss or Mrs Karairai). Of the 183 Kiribati vernacular names, 66 probably fall into the category of "proper names", 41 are classified as "descriptive names", 63 as "Kiribatizations" of other names, 7 as referring to the origin or persons responsible for introduction, and 6 which do not seem to fit into any of these categories(Table 2).

Table 2. Numbers of Kiribati vernacular names falling into different classes for indigenous species and

exotic pre-European contact aboriginal introductions and recent post-European contact introductions (te kaina, Pandanus tectorius, is included in indigenous, rather than aboriginal).

	Proper Names	Descriptive Names	Kiribatized Names	Person's/ Place Names	?	TOTAL
Indigenous	58	6	2	-	-	66
Aboriginal	6	-	2	-	-	8
Recent	-	34	58	7	6	105
Extinct	2	1	1	-	-	4
TOTAL	66	41	63	5	8	183

Proper Names

Of the 66 "proper names", 58 are names for indigenous species, six are food crops of aboriginal introduction, namely te ni(coconut), te mai, which refers to two species of breadfruit, te babai (giant swamp taro), te makemake (Polynesian arrowroot), and te taororo(true taro). Luomala (1953:66) suggests that te touru may have been the pre-contact Kiribati name for a banana cultivar presumably present prior to European contact, but now replaced by recently introduced clones. Two possibly extinct or non-existent species te barariku (Dioclea reflexa), which may only be known from drift seed and te kiriawa (Ficus sp.) make up the balance of the proper names.

The eight possibly indigenous plants having no proper name are Dodonea viscosa, which is known as te kaiboia (smelly plant), Vitex trifolia, known as te kaitu (the oozing tree or plant), Tribulus cistoides, te maukinikin(extreme or passionate pinch), three species of fungus, all te taninganiba(tasteless or repulsive ear), and two sedges, Cyperus odoratus and C. polystachyos, both known as te titania (reportedly the Kiribatization of Zizania). There is some doubt, however, as to whether all these are indigenous, as Overy, et. al., 1982:65) say that Dodonea viscosa is thought to have been introduced about 1945, and Vitex trifolia is only listed as present on Abiang (Fosberg, et al. 1979:239), may be an introduction from either Banaba (Ocean Island) or Nauru, where it is native and where it is called dogaidu (Thaman, et. al. (1985) (thus the tentative association of the Kiribati cognate te kaitu with V. trifolia). Similarly, the two Cyperus species, although reported as indigenous in many island groups, could possibly be naturalized exotics in Kiribati.

Most of the proper names are very distinctive and have no alternative meaning listed in Sabatier and Oliva's Gilbertese-English Dictionary(1971). These names include te aitoa, ter ango, te inato, te itai, te ukeuke, te ukin, te uri, te mao, te maukinikin, te mtea, te nika, te nimareburebu, te namatore, te non, te ntanini, te ngea, te baireati, te bero, te bingibing, te boi, te buangi, te buka, te bukare, te kaitu, te kanawa, te kaura, te keang, te kiaiai, te kiaou, te kimarawa, te kitoko, te kunikun, te reiango, te ren, te ruku, te tarai, te tongo, and te wao. Te uteute is the generic name for all indigenous grasses, while te maunei and te ritanin apply to indigenous sedges. The name for Pandanus tectorius, te kaina,

seems to also be a proper name, but could also be translated as "the tree" or the "one" tree(te kai plus the suffix na which can mean one), because of its dominant cultural importance.

Eleven additional possibly "proper names", for which there are no botanical indentifications, appear among Ratieta's 1946 list of 76 "local" plants. These include te aiao, te arabaotin, te bata, te bau, te bitikaina, te ikaeariki, te kaimaiu, te kobukobu, te kuao, te obu, and te rauota. Based on her study Luomala (1953) added an additional 18 names without botanical names. These are te bakare, te baranrenga, te betere, te ieretia, te itaia, te kaiaroua, te kaiegig, te katabono, te maokiki, te nimrona, te nini, te ntarine, te ntarrai, te ranga, te renga, te tarine, te vekera and te uri tabuki.

Of these only te kaimaiu (meaning the living, fresh, or flourishing tree) "a species of tree, very rare, used in carpentry", te tarine, "name of a tree, and te nimrona," a "marine moss adhering to seagoing craft" are listed as distinct plants in Sabatier and Oliva's (1971) dictionary. Te bakare, te itaia, te kaiaroua, and te maokiki were listed among trees or shrubs in an undated Gilbertese grammer prepared at the Sacred Heart Mission, te katabono and te uritabuki described as trees reported to be trees by Luomala's informants, and te nini reportedly refers to palms other than coconuts. Some of the balance are possibly synonyms for other plants, e.g. te ntarine and te ntarrai are probably synonyms for te tarine and te tarai, as Luomala (1953:105) says that "the initial m is often added before t", some, such as te arabaotin, which is listed as a Pandanus cultivar, are probably distinct cultivars or varients of other species, and some like te baranrenga, te ieretia, te kaiegig, te renga, and te uekera are reportedly the names for mythical or ancestral trees prominant in Kiribati cosmogeny, rather than plant species which may have existed in Kiribati in the past (Luomala, 1953; Sabatier and Oliva, 1971).

In terms of possible matches of these Kiribati names with species which have been reported to be present in Kiribati (Fosberg and Sachet, 1987), similar plant names or cognates from other Pacific island languages provide some clues. For example, te aiao might be the Kiribati for Ficus prolixa (also possibley te kiriawa), known in Nauru as eyayo or eaeo; te bao could be Neisosperma oppositifolia, known as fao in Tonga, Samoa, and Tokelau and as pao in Niue; and te renga could be turmeric (Curcuma longa), known as cago or rerega (pronounced rerenga) in Fiji, ango or enga in Tonga, renga in the Cook Islands, 'olena in Hawai'i, and ong in Ponape.

Descriptive Names

The descriptive names are usually Kiribati words which describe plant characteristics, things that they are associated with, or other plants that they resemble. Some of the descriptive names for the more common plants include te aronga (meaning scarcity or famine, the reason for this being unclear, unless it is in fact a "proper" name previously applied to similar indigenous Acalypha amentacea varieties, such as A. amentacea var. grandis, which may have been present in the past, and are reportedly indigenous elsewhere in Micronesia (Fosberg, et.al 1979; Fosberg and Sachet, 1987)); te uti (head lice) because of the lice-like appearance of the flower buds of Stachytarpheta jamaicensis and S. urticaefolia; te mam (fresh water) after the freshwater swamps and taro pits where Ludwigia octovalvis is found; te baraki (upside down) after its bell-shaped flower which encases the fruit of Physalis angulata and P. peruviana; te buraroti (rose-like) owing to the rose-like (to I Kiribati) flowers of Catharanthus roseus (the Latin specific name for which also meaning rose-like); te bumorimori (soft bud) for the giant milkweed or crown flower (Calotropis gigantea); and te kabekau (painted lady, harlot or prostitute) for the brightly painted Euphorbia cyathophora. Te kateketeke (thorn or burr) is used for burr grass (Cencrus echinatus); te riti (wick) for Canna indica and Canna hybrids, owing to the wick-like portion of the inflorescence; and te ruru (trembling) for Hymenocallis littoralis and some other lilies.

The word kai, meaning tree, bush, or plant, is part of many descriptive plant names. For example,

te kaibaba (plant or rope tree) is used for bamboo; te kaibakoa (shark tree) for the thorny Acacia farnesia; te kaibaun (golden tree) for the beautiful red-orange flowered Russelia equisetiformis; te kaibuaka (bad plant) for the noxious but beautiful Lantana camara; te kaikare (curry bush) for Pluchea symphytifolia, with its curry-like odor; te kaimatu (sleeping plant) for Phyllanthus amarus; and te kaimamara (we weak tree or bush) as one of two names for some of the many-stemmed Polyscias species, the other name being te toara (the odd number) because of its odd-numbered leaflets.

Te kaibake (tobacco plant) and te kaisoka (sugar plant), although descriptive, combine both descritive aspects as well as the Kiribatization of the words tobacco (bake) and sugar (soka). Chilli peppers (Capsicum spp.) are known as te beneka (vinegar), presumably because, to I Kiribati, they had the same "bite" or spicyness that vinegar had or because they were originally preserved in vinegar in the colonial days to make a hot sauce for food. The synonym for te babaia, te mwemweara, commonly used for papaya (Carica papaya), although having no specific meaning in the dictionaries, possibly means "that which can be lifted or which is not heavy", possibly referring to the very light hollow stalk (Sabatier and Oliva, 1971: 254).

As mentioned above, the only six possibly indigenous plants have "descriptive"rather than proper Kiribati names. These are te kaiboia (smelly plant)(Dodonea viscosa), te kaitu (oozing plant) (Vitex trifolia), te maukinikin (extreme or passionate pinch) for the weedy spreading and thorny perennial Tribulus cistoides, and three fungi, all te taninganiba (tasteless or repulsive ear), presumably because of their taste or appearance. The adjectives bubuti (spreading) and matutu (sleeping) are also used to differentiate between two "properly named" indigenous te nika species, te nikabubuti (Sonneratia alba) and te nikamatutu (Sophora tomentosa).

The "proper" name te boi is used for the exotic Portulaca oleracea, and te tarai for as many as 7 introduced weedy species of Euphorbia as "descriptive" name because of their similarity to the indigenous species Portulaca lutea and Euphorbia chamissonis respectively. Similarly, almost all introduced grasses and some weeds are referred to as te uteute, the "proper" name formerly reserved for indigenous grasses, but now having taken on a meaning closer to "weed". The term ibugibugi is used much the same in Nauru to refer to both indigenous grasses and some recently introduced weeds. Finally, the name te taororo for the aboriginally introduced taro (Colocasia esculenta) is also applied to tannia or American taro (Xanthosoma sagittifolium) because of its similar appearance and utility, and te mai rekereke (caught or captured) for the jackfruit (Artocarpus heterophyllus) because of its similarity to the breadfruit te mai (Artocarpus altilis).

Kiribatized Names

The 63 "Kiribatized" names consist mainly of plant names in English or other languages, which have been re-written according to the way I Kiribati pronounce the name and using the most appropriate orthography (letters) from the 13-character Kiribati alphabet. All "Kiribatized" plant names apply almost exclusively to exotic ornamental and food plants of post-European contact introduction, but also to a limited number of other useful plants and weeds.

Some of the more common Kiritatized names for ornamentals include te ang (air or wind) for the air plant (Kalanchoe pinnata); te aoaaua (four-o'clock) or te aoaua for the "four o'clock" (Mirabilis jalapa); te orian for the oleander (Nerium oleander); te meria (after the Hawaiian name melia) for Plumeria rubra and P. obtusa; te merikora(merigold) for Tagetes erecta; te bam (palm) for the Pacific fan palm (Prichardia pacifica), as well as for the palm-like cycad (Cycas circinalis); te bitati (from the Hawaiian pikake) for Jasminum sambac; te katia for ornamental cassias trees (Cassia spp.); te kiebu (probably an adaptation of the Nauruan dagiebu or dagibu) for three species of Crinum lilies, which were probably first introduced from Nauru; te rauti (after the Polynesian names rauti or lau si) for

Cordyline fruticosa; and te tinia (zinnia) for Zinnia elegans.

Kiribatized names for non-tree food plants include: te anian for onions (Allium spp.); te iam for yam (Dioscorea sp.) and te kabe (from the Polynesian kape) for the giant taro (Alocasia macrorrhiza), which both may have been aboriginal introductions, but, in the case of te kabe, now almost exclusively an ornamental; te meren for both watermelon and cantaloupe (Citrullus lanatus and Cucumis melo vars.), nambere (after the Fijian word na bele) for Hibiscus manihot); te baigan (after the Fiji Indian Hindi word for eggplant) for Solanum melongena);, te bainaboro for pineapple (Ananas comosus); te baukin, te bamakin or te bangke for pumpkin (Cucurbita pepo); te bin (bean) for both the long bean (Vigna sesquipedalia), as well as a synonym for te baraki, the bean-like bladderberry, ground cherry or cape gooseberry (Physalis spp.); te boro (after the Fijian boro, the general name for pepper like Solanum species) for the bell pepper or sweet capsicum (Capsicum annuum var. grossum); kabiti n Taina (Chinese cabbage and kabiti ni Imatang (Whiteman's cabbage) for non-heading and heading Brassica cabbage species, respectively; te kangkong (from the Philippine cangcong) for water convolvulus (Ipomoea aquatica); te kiukamba for cucumber) (Cucumis sativus); te kon or te kon for corn (Zea mays);
te kumara after the Maori word kumara used in New Zealand and the Cook Islands or kumala used in Tonga, Fiji, and elsewhere for the sweet potato (Ipomoea batatas); te tabioka (after the Fijian term tavioka) for cassava (Manihot esculenta); and te tomato (tomato) for Solanum lycopersicon.

Names for the more commonly grown fruit trees include te babaia or te mwemweara for the papaya or pawpaw (Carica papaya); te banana, which refers generally to all banana clones, although te umuumu (earth oven or cooked), te oraora (ripe or raw), and te wae (big leg) are sometimes used as descriptive terms to differentiate clones (Table 4); te biku for the edible fig (Ficus carica) (biku being the Kiribati rendition of "fig"); and te raim lime (Citrus aurantiifolia).

Other uncommon or rare fruit tree names include te aoranti (orange) (Citrus sineusis), which has never become established; te ibi, the Polynesian chestnut (Inocarpus fagifer) (presumably from the Polynesian ifi or the Fijian ivi, but which may either be extinct, or only a tree of Kiribati myth and legend); te mangko the mango. (Mangifera indica) and te kuwawa the guava (Psidium guajava), are both rare in Kiribati; and te remen or te remon for the lemon (Citrus limon).

Among the weedy species te mota or te moota (from the Fijian moca, pronounced motha) for Amaranthus species (a number of which have been cultivated or protected by the Kiribati Women's Federation (AMAK) as food plants), although Sabatier and Oliva (1971:400) suggest that an alternative name might be te uekeueke, which is said to be a bush "Amaranthus gracilis". This, however, may be only an alternative spelling for the ukeueke, and a misidentification of Laportea ruderalis. Te katia (Cassia) is reportedly the vernacular name for the weedy Cassia accidentalis, although it is listed by Luomala (1953:86) as also pertaining to either Cassia or Acacia spp., probably one of the common ornamental Cassia which she describes as a 15-20 foot high tree introduced into Tabiteuea from Banaba.

The name te titania reported by Bingham, 1953 in Luomala 1953:108 to be the Kiribati form of zizania, probably Zizania latifolia, a course aquatic grass yielding a food kau sun eaten by the Chinese, (Neal, 1965:71) applies to both Cyperus odoratus and C. polystachyos, presumably either because of their similarity to zizania plant which might have formerly grown experimentally in Kiribati, possibly by the Chinese, or because the name was introduced with these sedges.

The names of other useful plants include: te baubau for cotton (Gossypium barbadense) is probably derived from the Fijian word for cotton vauvau; te katurina, te katuarina, or te burukam (blue gum) for Casuarina equisetifolia (it could be that blue gum or Eucalyptus species were also introduced as part of reforestation or tree planting programmes along with casuarina?); te robu or te

rob (rope) for the fibre-yielding sisal plant (Agave rigida); and te roti (rose) for the rose (Rosa spp.) and two other plants considered by I Kiribati to have rose-like flowers, Hibiscus rose-sinensis (and hybrids) and Zephyranthes rosea.

The seven plants named after persons responsible for their introduction or after their place of introduction include: te uri n Tiana (the Guettarda speciosa-like plant from China) for Datura metel), possibly because it was first introduced by one of Kiribati's resident Chinese families; neikarairai (Mrs. or Miss Karairai) reportedly introduced by this person; te kaura ni Banaba (the Sida fallax-like plant from Banaba) for both Abutilon indicum and Wollastonia biflora, the yellow flowers of which were presumably thought to resemble the flowers of the indigenous te kaura and which were both probably introduced by Kiribati contract phosphate mine workers from Banaba (Ocean Island) where they are native; te ruru ni Buranti (the lily from France) (Rhoeo spathacea), probably because it was introduced into Kiribati by Catholic missionaries from France; and te kaitetua (law or government tree) for the poinciana (Delonix regia) and te tua (law or government) for leucaena (Leucaena leucocephala), reportedly because they were both introduced by the "government" and originally planted around government buildings.

Five Kiribati plant names were not categorized because it was not possible to find a Kiribati meanings or "Kiribatizations" of any recognizable plant name in English or other languages. These include te iaro (Pseudoeranthemum carruthersii vars. and P. laxiflorum); te marou for both Ocimum sanctum and O. basilicum; te motiti for the everlasting flower or bachelor's button (Gomphrena globosa); and te mumute for the widespread noxious weed, the nut sedge (Cyprus rotundus). Some of these, however, probably do have meanings in Kiribati or are Kiribatizations of some, at present underdetermined, plant names or characteristics.

SUMMARY

In summary, the I Kiribati, like most rural people who are closely tied to the fruit of the land and sea for their material and non-material wellbeing, know their natural plant and animal worlds exceedingly well and have local vernacular names for almost all indigenous and aboriginally introduced cultural plants (te aroka). Similarly, the I Kiribati, as well as the non-Kiribati people who have lived in this island world, have always and will continue to have an interest in new plants that can enhance the quality of their lives. Missionaries, European and Chinese residents, agriculturalists, colonial administrators, and many others have continually introduced and tested, in the harsh atoll environment, a wide range of plants. Similarly, the I Kiribati, in their pre-historic contact with other islands, and, more recently, through their contact with Banaba (Ocean Island), Nauru, and Fiji as contract workers and settlers, and with other islands countries and peoples, as a result of an expansion of shipping and air transport, have probably always introduced and will undoubtedly continue to introduce new plants into their home islands.

Of the just over 290 distinct plant species which have been reported present in Kiribati, just under two-thirds have Kiribati vernacular names: "proper" pure Kiribati names for most of the some 66 indigenous and 8 aboriginally introduced species and a mixture of descriptive "Kiribatized" and origin-related names for most of the 105 recently-introduced exotics. Together, these indigenous and exotic plants, particularly those with Kiribati names, constitute a critical ecological and cultural resource which must be seen, along with marine resources as the main bases for any future development and improvement or maintenance of quality of life in Kiribati. Te ni (coconut), te mai (breadfruit), te babai giant swamp taro, te kaina (pandanus), and, on some of the drier islands to the south, te bero (the native fig) will almost surely remain the dominant local staples; and the coconut, pandanus and a range of other plants will probably be the main sources of fuel, fibre, compost (fertilizer), medicines, perfumes, ornamentation, and other culturally important items. Given Kiribati's limited scope for economic development, extreme fragmentation, and isolation from metropolitan areas, plants will

remain critical to subsistence. Similarly, Kiribati myth, legend and the society's spiritual health are also inextricably tied to the plant world.

Although Kiribati elders know their plant world well, and know the names of almost all plants, old and new, many of the younger generation do not. To know ones plant world, just like really "knowing" the people of ones society, it is almost essential that one knows names. It is hoped that this paper and the list of Kiribati plant names (Table 3) which will hopefully be corrected, amended, and improved by others, may help in some way to prevent todays te roronga (Kiribati youth) and their descendents from becoming divorced from their lifegiving plant world, by helping them to "know" their names.

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ORGANIZATION OF THE PLANT LIST

The list of Kiribati, Latin, English and other selected vernacular names of plants for which recognized Kiribati names exist , in Table 3, is organized in Kiribati alphabetical order of the first letter of each name (exclusive of the te which precedes most names). The 13 characters of the Kiribati alphabet are placed in the following order: the vowels a,e,i,o, and u first, followed by the consonants and ng in the order m, n, ng, b, k, r, t, and w. Within each of these letter groupings all names are arranged in the order of the common Latin alphabet, however, a, a, b, e, i, k, m, n, ng, o, r, t, u, w (the 13 characters) to simplify the location of individual names by English readers. None of these last five consonants (b, k, r, t, or w) can end a word nor stand together, except bw.

As stressed by Cowell, (1950:1), the restricted orthography accounts for some confusing letter sounds. The vowels are generally pronounced: a as in father; e as in a in fate, although sometimes as the e in ten; i as ee in see; o as o in note, or sometimes as o in Bonny or aw in awful; u as oo in boot; m and n as in English; ng as the ng in sing or the gn in gnaw; b sometime like an English b, sometimes

like an English p, often a sound in between both, or even like a sound between a b and v; k is pronounced hard, often sounding more like a g (e.g. Kiribati sounds more like it should be spelled Giribas in English); r as an unrolled English r; t like a normal t before the vowels a, e, and o, with ti being pronounced si or tsi, and tu being pronounced too, soo, or tsoo (e.g. Kiritimati is pronounced like Christmas in English and katuru is pronounced as it it were kasooroo in English; and w like a w in English, but also as a bilabial in some cases (Cowell, 1951: 2-3).

The article te, which almost always precedes a plant name, is an integral part of a name and is found in almost all names except those named after people e.g. neikarairai (Mrs or Miss Karairai) or in cases where a name is a direct Kiribatization of a foreign name, e.g. the nambere from the Fijian na bele(pronounced nambele).

Kiribati synonyms are double listed in Table 3, giving the sources for each. Widely used Latin synonyms for some species are also included, as well as whether the species is believed to be indigenous, of aboriginal introduction, a recent post-European contact introduction, or extinct or non-existent, and whether the introduced species are decorative or ornamental plants, food plants, plants with other cultural uses, or weedy species.

Common English names are provided as well as other vernacular names, often from the Pacific, from which the Kiribati vernacular names might have been derived. Where available, other Micronesian equivalents or cognates from Nauru and the Marshall Islands have been provided for linguistic comparison.

Table 3. Kiribati, Latin, English, and selected other vernacular names for plant species having recognized Kiribati names (Notes: 1) the Kiribati alphabet consists of 13 characters which are arranged in the following order: 1) a, e, i, o, u, m, n, ng, g, b, k, r, t, and w. 2) the article te, which is almost always used before a noun, is seen as being an integral part of the name and is found before almost all plant names except those named after people, eg. neikarairai or in some cases where the name is a direct "Kiribatization" of a non-Kiribati name, e.g., nambere from the Fijian na bele. 4) * indicates that there are two or more reported Kiribati names for a given species, all of which have been listed in alphabetical order, or, in some cases, after the most widely accepted name. 5) There are recognized southern and nothern I Kiribati dialects, the N after a name indicating that a given name is used in the northern islands, whereas no designation indicates that it is a more universal name or of southern Kiribati origin. 6) The L, C, S, O, and T after the Kiribati names indicate which sources included that name along with the correct botanical name, L = Luomala, 1953, C = Catala, 1956, S = Sabatier and Oliva, 1971, O = Overy, Polunin, and Wimblett, 1982, and T = in-the-field survey by Thaman, 1984, with the lower case letters indicating that the name was included with either no botanical name or an incorrect identification. 7). Where the Kiribati name has an English translation, the meaning is provided in parentheses. 8) A ? after the Kiribati or botanical name indicates that either the Kiribati name is doubtful, or the the Latin botanical name corresponding to the vernacular name has not been verified in the field or with herbarium specimens. 9) Under "Latin Name", (I) = indigenous species, (A) = aboriginal introduction, (R) = recent, post-European-contact introduction, (E) = possibly extinct or never existing in Kiribati; D = decorative, ornamental, or groundcover plant, F = food plant, W = weedy species, and O = other specified cultural utility. 10) Under "Vernacular Names", those with no designation are in English, while others are designated after the name(s)

KIRIBATI NAME(S)	LATIN NAME	VERNACULAR NAMES
A		
te aitoa(l,C,S, O,T);te tongo-kai(L)	Lumnitzera littorea (Jack) Voigt (I)	
te akanta(l,s,T)	Bougainvillea glabra Choisy (R),D	bougainvillea, red bougainville
te akanta(l,s,O,T) x	Bougainvillea spectabilis Willd. (R),D	bougainvillea, purple bougainvillea
te anian(l,s,T)	Allium ascalonicum L. (R),F	shallot, Japanese or Welsh, bunching onion
te anian(l,s,T)	Allium fistulosum L. (R),F	green onion, spring onion
te ang(air)(L,C S,O,T)	Kalanchoe pinnata (Lam.) Pers.; syns. Bryophyllum pinnatum (Lam.) Kurz.; B. calycinum Salisb. (R), D	life plant, air plant, miracle plant
te ango (L,C,S,O,T)	Premna serratifolia L.; syns. P. obtusifolia R. Br.; P. integrifolia L.; P. taitensis Schauer (I)	kar, kaar (Marshall Is.), idibener, idibenerr (Nauru)
*te anti(O); see te kateketeke (thorny,sharp) (s,O,T)	Cenchrus echinatus L. (R),W	burr grass, sand burr; eakung iakung(Nauru)
te aoaaua (L,T) marvel of te aoaua(L); te te auaua(O); te te aoua(C); te awaaua(O); te awaawa(S)	Mirabilis jalapa L. (R),D	four o'clock, (four o'clock); Peru; teoua, teowa(Nauru)
te aoranti (orange)(l)	Citrus sinensis (L.) Osbeck (R),F	orange, sweet orange

te aroma(l,s)	Pipturus argenteus (Forst.f.) Wedd. var. argenteus? (I)	armea(Rotuma); arme,: areme arume(Marshall Is.)
te aroa(O,T); te marou(L)	Suriana maritima L. (I)	niienge,kanangi (Marshall Is.)
te aronga(scarcity or famine)(c,s o,t)	Acalypha amentacea Roxb. var. grandis (Benth.) Fosb.?; syn. A. grandis Benth. (E?),	
te aronga(scarcity or famine)(C,S, O,T)	Acalypha amentacea Roxb. ssp. wilkesiana (Muell.-Arg.) Fosb. f. circinata (Muell.-Arg) Fosb.; syn. A. wilkesiana Muell.-Arg. f. circinata Muell.-Arg. (R),D	
te aronga(scarcity or famine)(C,S, O,T)	Acalypha amentacea Roxb. ssp. wilkesiana (Muell.-Arg.) Fosb. f. wilkesiana; syn. A. wilkesiana Muell.-Arg. (R),D	copperleaf, beef-steak plant, Joseph's coat; Kayser bush (Nauru)

I

te iam(l,s)	Dioscorea sp. (R),F	yam
te iaro(C,S,O,T)	Pseuderanthemum carruthersii (Seem.) Guill. var. carruthersii (R),D	false eranthemum
te iaro(C,S,O,T)	Pseuderanthemum carruthersii (Seem.) Guill. var. atropurpureum (Bull) Fosb. (R),D	purple false eranthemum
te iaro(C,S,O,T)	Pseuderanthemum laxiflorum (Gray) Hubb. (R),D	false eranthemum
te inato(S,O,T); te inoto(L,S,O)	Clerodendrum inerme (L.) Gaertn. var. oceanicum A. Gray	beach privet; eamwiye, eyamwiye, eamwije, eayamwije (Nauru)
te ibi(l,s) (E?),F	Inocarpus fagifer (Park.) Fosb.; syn. I. edulis Forst.	Tahitian chestnut, Pacific chestnut

te itai(L,C,S,O,T)	Calophyllum inophyllum L. (I)	Alexandrian laurel, portia tree, tomano; kamani(Hawaii); luej, luech (Marshall Is); iyo, ijo(Nauru)
O		
*te oraora(to eat raw),(T); see te banana(L,C, S,O,T)	Musa (AAA Group) äMysore' Simmons (R),F	lady's finger banana; tama-tama ai lima (Tuvalu); dabanana(Nauru)
te orian(l,S,O,T)	Nerium oleander L. var. oleander (R),D	oleander
te orian(l,S,O,T)	Nerium oleander L. var. indicum (Mill.) Deg. & Deg. (R),D	oleander
U		
*te uekeueke(S); see te mota (T); te moota (T)	Amaranthus dubius Mart. ex Thell.; syn. A. gracilis sensu Catala and Guillaumin, non. Desf.	spleen amaranth; moca(pro-nounced motha) (Fiji)
te ukeuke(s,O,T); te uekeuke(l) te nekeneke(S)	Laportea ruderalis (Forst.f.) Chew; syn. Fleurya ruderalis (Forst.f.) Gaud. ex Wedd. (I)	nen ketekut (Marshall Is)
te ukin(l,s,O,T)	Terminalia samoensis Rech.; T. littoralis sensu auct. non Seem. (I)	eking, kukung, akungkung (Marshall Is.)
te uri(L,C,S,O,T); te uri rara(O)	Guettarda speciosa L. (I)	guettarda; wut (Marshall Is.); iut,yut(Nauru)
te uri n Tiaina (China)(C,O)	Datura metel L.; syn. D fatuosa L. (R),D	datura, thorn apple, jimson weed, cornu-copia
te uteute(grass) (C,T)	Chloris inflata Link; syn. C. barbata sensu Sw. non (L.)Sw. (R),W	finger grass

te uteute(grass) (C,T)	Dactyloctenium aegyptium (L.) Willd. (R),W	four-finger grass, beach wire grass
te uteute(grass) (C,T)	Digitaria setigera Roth in R. & S.; syns. D. pruriens (Fisch. ex Trin.) Buse; D. microbachne (Presl) Henr. (I?)	itchy crabgrass
te uteute(grass) (L,C,O,T);te uteutena-banabana (hollow grass)(L)	Eleusine indica (L.) Gaertn. (R),W	goose grass, crow'-foot grass
te uteute(L,O,T)	Lepturus repens (Forst.f.) R. Br. (I)	
te uteute(C,O,T)	Paspalum distichum L.; syns. P. vaginatum Sw.; P. littorale R. Br. (I)	saltgrass, couch grass, knot grass, seaside paspalum
te uteute(grass) (C)	Stenotaphrum micranthum (Desv.) Hubb. (I?)	
te uteute(O,T)	Thuarea involuta (Forst.f.) R. Br. ex R. & S. (I)	
*te uteute ae kateketeke(L); see te kateke-teke(L,C,S, O,T); te anti(O)	Cenchrus echinatus L. (R),W	burr grass, sand burr
te uteute n' aine(female) (L,C,S,O,T); te uteute te aine(L)	Eragrostis amabilis (L.) W. & A. ex Hook; syn. E. tenella (L.) Beauv. ex. R. & S. (I?)	love grass
te uteute ni mane(male)(S,T); te uteute ni mmane(O); te uteute te mane(L,C)	Fimbristylis cymosa R. Br.; syn. F. atollensis St. John (I)	beach sedge

te uti(head lice) (l,C,s,O,T)	Stachytarpheta jamaicensis (L.) Vahl. (R),W	Jamaica vervain; edidubai, edidubaiy (Nauru)
te uti (head lice) (T)	Stachytarpheta urticaefolia Sims (R),W	blue rat tail, vervain

M

te mai(L,C,S,O,T); te bukiraro (O,S,T), te mai bukiraro(T)	Artocarpus altilis (Park.) Fosb. (A),F	breadfruit; ulu(Samoa); mei(Tonga, Tuvalu); mei, me, ma(Marshall Is.);deme(Nauru)
te mai(C); te keang ni Makin(C)	Artocarpus altilis x mariannensis (A?),F	hybrid breadfruit
te mai rekereke (caught or captured) (LG,.S)	Artocarpus heterophyllus Lam. (E),F	jackfruit
te mai(C,O,T); te ,aitarika(C), te mai keang(o), te mai kora(T)	Artocarpus mariannensis Trec. (A),F	Marianas bread-fruit; damen-kamor(Nauru),
te makemake (L,C,S,O,T)	Tacca leontopetaloides (L.) O. Ktze. (A),F arrowroot;	Polynesian arrow-root, Pacific

mokemok, mokmok(Marshall Is);damagmag (Nauru),

te mam(fresh water)(C,O,T)	Ludwigia octovalvis (Jacq.) Raven; syn. Jussiaea suffruticosa L. (R),W	false primrose, swamp primrose
te mangko(L,C, S,T);te manko(C)	Mangifera indica L. (R),F	mango; damangko (Nauru)
te mao(L,C,S,O,T)	Scaevola sericea Vahl; syn. S. taccada (Gaertn.) Roxb. var. sericea (Vahl)	salt bush, half-flower; gunnat, kunnat, konnat,

	St. John (I)	kannat, kunat, kenat, kinnat, mar(Marshall Is.);emet, emed (Nauru)
te marou(l,C,T)	Ocimum basilicum L. (R),F	sweet basil; dementsi(Nauru)
te marou(l,O,T)	Ocimum sanctum L. (R),D	sweet basil; tulsi(Hindi); demere(Nauru)
*te marou(L); see te aroa(O)	Suriana maritima L. (I)	
te maukinikin (extreme or passionate pinch)(O)	Tribulus cistoides L. (I)	puncture vine
te maunei(L,C,s, o,T)	Cyperus laevigatus L. (I)	smooth flat sedge, makaloa sedge (Hawaii)
te maunei(C,s)	Eleocharis geniculata (L.) R. & S. (I)	sedge
te meren(l,T)	Citrullus lanatus (Thunb.) Matsum & Tan. var. caffrorum (Alef.) Fosb; syn. C. vulgaris Schrad. ex Eckl. & Zeyh. (R),F	watermelon
te meren(l,T)	Cucumis melo L. var. cantalupensis Naud. (R),F	rock melon, cantaloupe
te meria(C,s,O,T)	Plumeria obtusa L. (R),D	white frangipani, plumeria
te meria(L,C,S, O,T)	Plumeria rubra L.; syn. P. acuminata Ait. (R),D	frangipani, plumeria, temple tree
te merikora(T)	Tagetes erecta L. (R),D	merigold, African merigold
te mota(T); te moota(T); te uekeueke(S)	Amaranthus dubius Mart.; syn. A. gracilis sensu Catala and Guillaumin, non Desf. (R),W	spleen amaranth; moca (pro-nounced motha) (Fijian)

te mota(T), te moota(T)	Amaranthus viridis L. (R),W	slender amaranth, pig weed, green amaranth; moca (pronounced motha)(Fijian)
te motiti(C,S); te moteti(l)	Gomphrena globosa L. (R),D	bachelor button, everlasting flower
te mtea(L,C,s, O,T)	Portulaca australis Endl. syns. P samoensis v. Poelln. (I),F	nat'te, buhang. (Marshall Is.)
te mumute(T)	Cyperus rotundus L. (R),W	nut sedge, nut grass
*te mwemweara (L,S,O,T); see te babaia (C,S,O,T)	Carica papaya L. (R),F	papaya, pawpaw, dababaia(Nauru)

N

nambere(T); te bere(T)	Hibiscus manihot L.; syn. Abelmoschus manihot (L.) Moench (R),F	hibiscus spinach; bele (Fiji); pele(Tonga, Samoa)
nei karairai (Miss or Mrs. Karairai)(T)	Tecoma stans (L.) Juss. ex HBK.; syn. Stenolobium stans (L.) D.Don. (R),D	yellow elder, yellow bells
*te nekeneke(S); see te ukeuke (s,O,T);te uekeuke(l)	Laportea ruderalis (Forst.f.) Chew; syn. Fleurya ruderalis (Forst.f.) Gaud. ex Wedd. (I)	nen ketekut (Marshall Is.)
te ni(L,C,S,O,T)	Cocos nucifera L. (A),F	coconut
te nikabubuti (spreading nika)(s,O)	Sonneratia alba J.E. Sm. (I)	white mangrove
te nika matutu (sleeping nika)(S,O) te kaimatu(S)	Sophora tomentosa L. (I)	silver bush
te nimareburebu	Hernandia sonora L.; syns.	lantern tree;

c (L,C,S,O,T); te bingibing (l,S,T)	H. ovigera sensu auct. non L.; H. nymphaeaefolia (Presl) Kubitzki (I)	pingping (Marshall Is.); etiu, yetiu (Nauru)
te nimatore (l,s,T); te kimatore(l,T)	Macaranga carolinensis Volk. (I)	macaranga
te non(L,C,S, O,T)	Morinda citrifolia L. (I)	beach mulberry; nonu(Tonga, Samoa, Tuvalu); noni(Hawaii); nen, nin (Marshall Is.); deneno(Nauru)
te ntanini (L,C,S,O,T)	Cassytha filiformis L. (I)	beach dodder; kaanin, kani, kanun, kenen (Marshall Is.); denuwanini (Nauru)

NG

te ngea(L,C, S,O,T)	Pemphis acidula Forst. (I)	pemphis; ngingie, (Tonga); ngiengie, kengi (Marshall Is.)

B

te babaia(C,S, O,T);te mwem-weara(L,S,O,T)	Carica papaya L. (R),F	pawpaw, papaya; dababaia (Nauru)
te babai(L,C,S O,T)	Cyrtosperma chamissonis (Schott.) Merr. (A),F	giant swamp taro; dababai(Nauru)
te baigan(T)	Solanum melongena L. (R),F	egg plant, aubergine; baigan (Fiji Hindi)
te bainaboro(L,T); te bainabora (L,S)	Ananas comosus (L.) Merr. (R),F	pineapple
te baireati(L,C,	Barringtonia asiatica	fish-poison tree,

O,T); te bairiati(L,S)	(L.) Kurz (I)	barringtonia; kwenbabai, kwenababai (Nauru)
te bam(palm)(O)	Cycas circinalis L. (R),D	cycad
te bam(palm)l,s, O,T)	Prichardia pacifica Seem. and Wendl. (R),D	Fiji fan palm; dabam(Nauru)
*te bamkin(L,T); see te baukin (L.C,O,T); te bangke(N)(L,T)	Cucurbita pepo L. (R),F	pumpkin; dabam-akin(Nauru)
te banana(L,C,S, O,T)	Musa(AAA Group) äRobusta' Simmons; syns. Musa x sapientum L., M. paradi-siaca L. ssp. sapientum (L.) O. Ktze. (R),F nana(Nauru)	Cavendish banana, Mons Marie, robusta; pisang Ambon(Indo-nesia); daba-
te banana(c,s,T); te oraora(to eat raw)(T)	Musa(AAB Group) äMysore' Simmons (R),F	Lady's finger banana; tamatama ai lima(Tu-valu); dabanana (Nauru)
te banana(T), te wae(leg)(T)	Musa(AAB) Group äMaia maoli' Simmons; syn. Musa x paradisiac L. (R),F	Plaintain; maia maoli(Tahiti); vudi(pronounced vundi)(Fiji); hopa(Tonga)
te banana(c,s,T), te umuumu(T)	Musa(ABB Group) Simmons (R),F	äBluggoe' Plaintain, bluggoe; bata (Fiji); pata (Tonga,Samoa, Tuvalu); dabanana(Nauru)
*te bangke(N) (L,T); see te baukin(L,C, O,T); te bamkin(L,T)	Cucurbita pepo L. (R),F	pumpkin; dabamakin (Nauru)
te baraki(upside down(C,o,T); te bin(bean) (l,C,O,T)	Physalis angulata L.; syn. P. minima sensu auct. non L. (R),W	cape gooseberry, bladderberry, ground cherry; oatamo, watamo (Nauru)

te baraki(upside down)(S,t); te bin(bean) (N)(l,T)	Physalis peruviana L. (R),W	cape gooseberry, bladder berry; oatamo, watamo (Nauru)
te barariku(l,S); te bararuku(l)	Dioclea reflexa Hook.f.? (E?)(drift seed?)	sea bean
te baubau(l,S, O,T); te baobao(l)	Gossypium barbadense L. (R),O	sea island cotton; duwoduwo(Nauru)
te baukin(L,C,O, T);te bamakin, (L,T); te bangke(N)(L,T)	Cucurbita pepo L. (R),F kin(Nauru)	pumpkin; dabama-
te beneka(vine-gar)(T)	Capsicum annuum L. var. acuminatum Fingerh. (R),F	long cayenne chili; epeba (Nauru)
te beneka(vine-gar)(L,C,O,T)	Capsicum frutescens L. (R),F	tobasco, peren-nial chili, bird chili; epeba(Nauru)
*te bere(T); see nambere(T)	Hibiscus manihot L.; syn. Abelmoschus manihot (L.) Moench. (R),F	hisbiscus spinach, bele (Fijian), pele (Tonga, Samoa)
te bero(L,C, S,O,T)	Ficus tinctoria Forst.f. var. neo-ebudarum (Summerh.) Fosb. (I),F	wild fig, Pacific fig, Dyer's fig; felo (Tuvalu); debero (Nauru)
te bero(L,C, S,O,T)	Ficus tinctoria Forst.f. var. tinctoria (I),F	wild fig, Pacific fig, Dyer's fig; felo (Tuvalu); debero (Nauru)
te biku(fig)(L,C, S,O,T)	Ficus carica L. (R)	common fig
the biku(fig)(O)	Passiflora foetida L. var. hispida (DC) Killip. (R),W	wild passionfruit, stinking passion flower; oatamo,watamo (Nauru)

*te bin(bean) (l,C,O,T);see te baraki(s,T)	Physalis angulata L.; syn. P. minima sensu auch. non L. (R),W	(cape gooseberry, bladderberry, ground cherry; oatamo, watamo (Nauru)
*te bin(bean) (l,T); see te baraki (S,T)	Physalis peruviana L. (R)	cape gooseberry, bladderberry; oatamo,watamo (Nauru)
te bin(bean)(s,T)	Vigna sesquipedalis (L.) Fruw.; syn. V unguiculata (L.) Walp. ssp. sesqui-pedalis (L.) Verdc. (R),F	long bean, yard-long bean, asparagus bean snake bean
*te bingibing (l,s,T); see te nimareburebu (L,C,s,O,T)	Hernandia sonora L.; syns. H. ovigera sensu auct. non L.; H. nymphaeaefolia (Presl) Kubitzki (I)	lantern tree; pingping (Marshall Is.); etiu, yetiu (Nauru)
te bingibing(L, C,S)	Thespesia populnea (L.) Sol. ex Correa (I)	milo(Tonga, Hawaii); itira, itirya(Nauru)
te bitati(l,S,T)	Jasminum sambac (L.) Ait. (R),D	Arabian jasmine, pikake(Hawaii); pitasi(Tuvalu); rimone(Nauru)
te boi(L,C,S,O,T)	Portulaca lutea Sol. (I)	seaside purslane; purya, kiran (Marshall Is.).
te boi(S,O,T)	Portulaca oleracea L. var. granulato-stellulata v. Poelln. (R),W,F	purslane, pig-weed; debois, deboiy(Nauru)
te boi(C,O)	Sesuvium portulacastrum L. var. griseum Deg. & Fosb. (I)	seaside pruslane
te boro(T)	Capsicum annuum L. var. grossum (L.) Sendtn. (R),F	bell pepper, sweet pepper, capsicum; boro (Fiji); polo (Tonga)
*te buangi(C); see te tongo	Bruguiera gymnorhiza (L.) Lam.; syn. B. conjugata	oriental mangrove; tongo(Tonga,

(L,C,s,T); te tongo buangi (L,s)	(L.) Merr. (I)	Samoa, Tuvalu); dogo(pronounced dongo)(Fiji); etum, etam (Nauru)
te buka(L,C,S, O,T)	Pisonia grandis R. Br. (I)	pisonia; puka tea (Tuvalu); puka (Samoa); puko (Tonga);kangl (Marshall Is.): yangis, yangits (Nauru)
te bukare(C,S)	Ruppia maritima L. var. pacifica St. John & Fosb. (I)	sea tassel, widgeon grass
te bumorimori (soft bud)(O,T)	Calatropis gigantea (L.) R. Br. (R),D	giant milkweed, crown flower
te buraroti (rose-like) (C,O,T)	Catharanthus rosea (L.) G. Don; syn. Vinca rosea L. (R)	Madagascar periwinkle, vincus
*te burukam(blue gum)(O); see te katurina	Casuarina equisetifolia L.; syn. C. litorea L. var. litorea (R),O	causuarina, iron-wood, she oak

K

te kabe(l,T)	Alocasia macrorrhiza(L.) G. Don (A?),D	giant taro; 'ape (Hawaii, Cook Islands, Hawaii); kape (Tonga)
te kabekau (painted wo-man, prosti-tute)(L,C, S,O,T)	Euphorbia cyathophora Murr.; syn. E. heterophylla sensu auct. non L. (R),W	wild poinsettia, false poin-settia, dwarf poinsettia, Mexican fire plant, hypo-crite plant; deriba, deribeh (Nauru)
te kabiti(cabbage); te kabiti n Tiaina(China) (T)	Brassica chinensis Juss. var. chinensis (R),F	Chinese cabbage, paak tsoi (Chinese)

te kabiti(cabbage); te kabiti n Tiaina(China) (T)	Brassica juncea (L.) Czern & Cossin (R),F	mustard cabbage, kai tsoi (Chinese)
te kabiti(cabbage), te kabiti ni Imatang (European)(T)	Brassica oleracea L. var. capitata L.; syn. B. oleracea var. bullata DC. (R),F	English cabbage, head cabbage
te kabiti(cabbage), te kabiti n Tiaina(China), (T)	Brassica XX hybrid (R),F	saladeer hybrid Chinese cabbage
te kaibaba(plank or rope tree) (s,L)	Bambusa sp. (R),O	bamboo;ebarabaratu (Nauru)
te kaibake (tobacco plant) (L,S,O,T)	Nicotiana tabacum L. (R),O	tobacco
te kaibakoa (shark tree); (O,T); te aketia(acacia) (l)	Acacia farnesiana (L.) Willd. (R),D	klu, aroma; debena(Nauru)
te kaibaun(golden plant)(L,C,S, O,T)	Russelia equisetiformis Schlect & Cham. (R),D	coral plant
te kaibuaka(bad plant)(O,T)	Lantana camara L. var. aculeata (L.) Mold. (R),D	lantana; migiroa (Nauru)
te kaibuaka(bad plant)(O,T)	Lantana camara L. var. camara (R),D	lantana; migiroa (Nauru)
te kaiboia (smelly plant) (l,C,O,T)	Dodonea viscosa (L.) Jacq. (I?)	native hop bush; eteweo, eteweau (Nauru)
te kaikare(curry bush)(O,T);te karei(O)	Pluchea symphytifoli (Mill.) Gillis; syn, P. odorata Cass. (R),W	stinking fleabane,, curry plant
te kaimamara(weak plant)(l,O)	Polyscias fruticosa (L.) Harms (R),D	panax
*te kaimamara(weak	Polyscias guilfoylei (Cogn.	panax, hedge panax

plant)(L);see te toara(the odd number)(C,S, O,T)	& March) Bailey (R),D	
te kaimatu(sleep- ing plant) (L,C,S,O,T)	Phyllanthus amarus Sch. & Th. (R),W; syn. P. niruri sensu auct. plur non L.	sleeping plant
te kaina(L,C, S,O,T)	Pandanus tectorius Park. (I & A?)	pandanus, screw pine; epo, epuh (Nauru)
te kaisoka (sugar plant) (T); te kai- karewe(toddy plant)(S)	Saccharum officinarum L. (R),F	sugarcane; tugage (Nauru)
te kaitetua(law or government tree)(T)	Leucaena leucocephala (Lam.) de Wit syn. L. glauca (L.) Benth. (R),O	leucaena; koa Haole (Hawaii)
te kaitu(oozing plant)(I)	Vitex trifolia L. var. bicolor (Lam) Mold.; syn. Vitex negundo L. var. bicolor (Willd.) Lam ? (I)	beach vitex; dagaidu, degaidu(Nauru)

te kanawa(L,C,
S,O,T)
	Cordia subcordata Lam. (I)	sea trumpet; kou
		(Hawaii); nawa-
		nawa(Fiji); pua-
		taukanave
		(Tonga); taua-
		nave(Samoa);
		kanava(Tuvalu);
		kano, koko
		(Marshall Is.);
		eongo, eoongo,
		eowongo(Nauru)

te kangkong(T); te ruku(O)	Impomoea aquatica Forsk. syn. I. reptans Poir. (R),F	water spinach, swamp cabbage, water convol- vulus; karamua (Fiji Hindi); horenso(Japan); Lorenzo (Nauru)
te kateketeke (thorn or burr)	Cenchrus echinatus L. (R),W	burr grass, sand burr;

(L,C,s,O,T); te anti(O)		eakung(Nauru)
te katia(cassia) (l,O,T)	Cassia occidentalis L. (R),W	coffee senna, arsenic bean; tan braua (sunflower) (Nauru)
te katia(cassia) (l,t)	Cassia sp. (R),D	cassia tree
te katiru(s,O,T); te katuru(N) (l,s,O,T)	Ixora casei Hance (R),D	ixora
te katurina(T); te burukam(O) (blue gum); te katuarina(O)	Casuarina equisetifolia L.; syn. C. litorea L. (R),O	casurarina, ironwood, she oak; tanenbaum (German for Christmas tree)(Nauru)
te kaura(L,C, S,O,T)	Sida fallax Walp. (I)	ilima (Hawaii); kio(Marshall Is.);ekaura, idibin ekaura (Nauru)
te kaura(L,C); te kaura ni	Abutilon indicum (L.) Sweet (R?), D or A. asiaticum var. Albescens (Miq.) Fosb.	Indian mallow; ekaura, Banaba(C) inen kaura (Nauru)
te kaura(L,S);te kaura ni Banaba(C,O)	Wollastonia biflora (L.) DC.; syns. Wedelia biflora (L.) DC.; Wedelia strigulosa DC. (R?),D	wedelia; marajej, marijetch, morijetch, marjatch, marjej, mojej, moredjet, moredjit, markeue, markueue, margueue, markebuebue, markubwebwe, markuwewe, merkuekue, mergwebit (Marshall Is.)

te keang(C,O,T); te keang ni Makin(S,T), te keang ini Makin(l,O)	Polyopodium scolopendria Burm.f.; syns. Phymatodes scolopendria (Burm.f.) Ching; and Microsorium scolopendria (Burm.f.) Copel. (I)	scented fern; lawai fern (Hawaii); dakeang, dageang(Nauru)
te keang(T); te keang ni Imatang(T)	Nephrolepis hirsutula (Forst.f.) Presl. (I)	sword fern; dakeang; dageang(Nauru)
*te keang ni Makin(C); see te mai(T)	Artocarpus altilis x marianensis (A?),F	hybrid breadfruit
te keang(C,S)	Thalassia hemprichii (Erenb.) Aschers. (I)	turtle grass; seagrass
te kiaiai(L,C,S, O,T);te rao (N)(C,S,T),te rau(O)	Hibiscus tiliaceus L. (I)	beach hibiscus tree; vau (Fiji); fau (Tonga, Samoa); burao(Tahiti); purau (Tahiti) hau (Hawaii); law (Marshall Is.) ekwane(Nauru)
te kiaou(L,C,S, O,T)	Triumfetta procumbens Forst.f. (I)	beach burr; at'al (Marshall Is.); ikiau,ikiow, igiau(Nauru)
te kiebu(l,C,S, O,T); te ruru (C,O)te ruru n aine(female (O)	Crinum asiaticum L. var. (R),D	spider lily, giant crinum lily; dagiebu, dagibu (Nauru)
te kiebu(L,S)	Crinum asiaticum L. var. pedunculatum (R. Br.) Fosb. & Sachet; syns. C. pedunculatum R. Br.; C. australe Don (R),D	kiep, kieb (Marshall Is.); dagiebu, dagibu (Nauru)
te kiebu(O)	Crinum augustum Ker-Gawl? (R),D	Queen Emma lily
te kimarawa(C,S) (Nauru)	Psilotum nudum (L.) Beauv. (I)	psilotum, reed fern; ibiribir

*te kimatore(l,T); see te nimatore(l,s,T)	Macaranga carolinensis Volk. (I)	macaranga
te kiriawa(l,s); te kiriaua(l)	Ficus prolixa Forst.f.? (E?)	native banyan
te kitoko(C,s,T)	Canavalia cathartica Thou.; syn. C. microcarpa (DC.) Piper (I)	Mauna Loa bean (Hawaii); manlap, marlap, (Marshall Is.); erekogo, irekogo (Nauru)
te kitoko(s,T)	Vigna marina (Burm.) Merr. (I)	beach pea; erekogo (Nauru)
te kuawa(T); te kuwawa(T)	Psidium guajava L. (R),F	guava,quwawa (Fiji); kuava (Tonga); kuwawa (Nauru)
te kukamba(T)	Cucumis sativus L. (R),F	cucumber
te kona(S,T), te kon(T)	Zea mays L. (R),F	corn, maize
te kumara(L,C, S,O,T)	Ipomoea batatas (L.) Lam. (R),F	sweet potato, kumara; kumala (Fiji, Tonga)
te kunikun(L,C, S,O,T); te tarin(O)	Terminalia catappa L. (I),F	beach almond, sea almond, Malabar almond, Indian almond; kutil (Marshall Is.); etetah, eteto (Nauru)

R

te raim(L,S,T)	Citrus aurantiifolia (Christm.) Swingle (R),F	lime; derem, deraim(Nauru)
*te rao(N)(C,S,T); kiaiai, (L,C,S,O,T); te rau(O)	Hibiscus tiliaceus L. (I)	beach hibiscus see te tree; vau (Fiji); fau (Tonga,Samoa); burao(Tahiti);

		hau(Hawaii); ekwane(Nauru)
te rauti(l,C,S, O,T)	Cordyline fruticosa (L.) Chev., syn, C. termin-alis (L.) Kunth (R?),D	cordyline; rauti (Cook Islands); si(Tonga); ti, ki(Hawaii); lauti(Tuvalu)
te reiango(l,s)	Cerbera manghas L.? (I?)	cerbera, poison apple; derei-ongo, derei-yongo(Nauru)
te remen(L,T); remon(S,T)	Citrus limon(L.) Burm.f. (R)	lemon
te ren(L,C,S,O,T)	Tournefortia argentea L.f.; syn. Messer-schmidia argentea (L.f.) (I) Johnst.	beach heliotrope; irin(Nauru)
te ritanin(l,C, S,O,T); te titania(O)	Cyperus javanicus Houtt.; syn. Mariscus javanicus (Houtt.) Merr. (I)	marsh cypress; sedge; reyenbangabanga (Nauru)
*te ritanin(L);see te titania(L, s,o,t)	Cyperus odoratus L.? (I)	sedge
te riti(wick)(O)	Canna indica L. (R),D	Indian shot, canna lily
te riti(wick)(O)	Canna x hybrida Hort. ex. Back (R),D	hybrid canna lily
te robu(rope) (l,c,s,o,T); te rob'(l); te kaibaba(O)	Agave rigida Mill. var. sisalana Perrine ex Engelm.; syn. A. sisalana Perrine ex	sisal, malina
Engelm. (R),O		
te roti(rose)		
Hib		
iscus rosa-sinensis L. (L,s,O,T)	hibiscus; dorot (R),D	(Nauru)
te roti(rose)(T)	Hibiscus ornamental hybrids (R),D	hybrid hibiscus

te roti(rose) (l,s,t)	Rosa multiflora Thunb. (R),D	rose
te roti(rose) (L,s,O)	Zephyranthes rosea (Lind.) Green (R),D	zephyr flower, zephyr lily, pink lady, pink star of Bethlehem
*te ruku(O); see kangkong(T)	Ipomoea aquatica Forsk. (R),F	swamp cabbage, te water convolvulus, cangcong (Philippines); ung tsoi (Chinese); horenso(Japan); Lorenzo(Nauru)
te ruku(T)	Ipomoea littoralis Bl., syn. I. gracilis sensu auct. non R. Br. (I)	
te ruku(L,C,S, O,T)	Ipomoea macrantha R. & S., syn. I. tuba (Sclecht.) G. Don (I)	moon flower; bele, marabele, marbele, maralap, (Marshall Is.)
te ruku(L,C,S, ruku maeao(O)	Ipomoea pes-caprae (L.) Sweet ssp. brasiliensis (L.) v. Ooststr.; syn. I. brasiliensis (L.) Sweet (I)	beach morning O,T); te glory, goat's foot morning glory; marji-ejojo(Marshall Is.); erekogo, irekogo(Nauru)
te ruru(trembling lily)(s,T); te ruru ni mmane(O)	Hymenocallis littoralis (Jacq.) Salisb.; syn. Pancratium littorale Jacq. (R),D	spider lily
te ruru ni lily of France?)(O)	Rhoeo spathacea (Sw.) Stearn; syn. R. discolor L'He'r. (R),D	oyster plant, Buranti(the tradescantia, Moses in a boat

T

te tabioka (tapioca)(l,T)	Manihot esculenta Cran M. utilissima Pohl. (R),F	cassava, manioc, tapioka;

		tavioka(Fiji)
te taninganiba (tasteless or repulsive ear) (L,s)	Earliella corrugata ? (I)	fungus
te taninganiba (tasteless or repulsive ear) (L,s)	Polyporus sanguinensis L. ex. Fries (I)	fungus
te taninganiba (tasteless or repulsive ear)	Myxomycetes (I)	fungus
te taororo(L,C, S,O,T)	Colocasia esculenta (L.). Schott (A),F	taro; talo(Tonga,. Samoa); taro (Cook Is., Tahiti); dalo, rourou(taro-leaf spinach) (Fiji); de taro (Nauru)
te taororo(T)	Xanthosoma sagittifolium (L.) Schott (R),F	tannia, cocoyam; detaro(Nauru)
te tarai(L,C,s, O,T)	Euphorbia chamissonis (Kl. & Gke.) Boiss.;syn. E. atoto sensu auct. non Forst.f. (I)	beach spurge; mal dok, beran, puripur (Marshall Is.)
te tarai(s,O,T)	Euphorbia geniculata Ortega (R),W	wild spurge
te tarai(s,O,T)	Euphorbia glomerifera (Millsp.) Wheeler (R),W	spurge
te tarai(C,s,O,T), te tarai Kutiaie(Kusaie, Korsre)(L,T)	Euphorbia hirta L. (R),W	spurge, asthma plant
te tarai(L,s,O,T)	Euphorbia prostrata Ait. (R),W	prostrate spurge
te tarai(s,T)	Euphorbia rubicunda Steud.; syn. E. thymifolia L. auct. non L. (R),W	thyme-leaved spurge
te tiare(l,T)	Gardenia taitensis DC. (R),D	Tahitian gardenia;

		tiare Tahiti (Tahiti); tiare Maori (Cook Islands); tieri(Rotuma)
te tinia(L,T)	Zinnia elegans Jacq. (R),D	zinnia
*te titania (zizania)(O); see te ritanin (l,C,s,O,T)	Cyperus javanicus Houtt. (I)	marsh cyperus
te titania (zizania) (L,s,o,t)	Cyperus odoratus L.? (I)	sedge
te titania(s,o,t)	Cyperus polystachyos Rottb. (I?)	sedge
te toara(the odd number)(l,C,S, o,T); te kai-mamara(L)	Polyscias guilfoylei (Cogn. & March) Bailey; syn. Nothopanax guilfoylei (Cogn. & March) Merr. (R),D	panax, hedge panax
te toara(the odd number)(T)	Polyscias scutellaria (Burm. f.) Fosb. (R),D	panax
te tomato(L,T)	Solanum lycopersicum L.; syn.Lycopersicon esculentum Mill. (R),F	tomato
te tongo(l,C,s, O,T)	Rhizophora mucronata Lam. var. stylosa Griff. (I)	red mangrove, American man-grove; dogo (pronounced dongo)(Fiji); tongo(Tonga); jong, chong (Marshall Is.)
te tongo(L,C,s,T); te tongo, buangi(L,s), te buangi(C)	Bruguiera gymnorhiza (L.) Lam.; syn. B. conjugata (L.) Merr. (I)	oriental mangrove; tongo(Tonga, Samoa, Tuvalu); dogo(pronounced dongo)(Fiji); etum, etam (Nauru)
*te tongo kai(L); see te aitoa (l,C,S,O,T)	Lumnitzera littorea (Jack) Voigt. (I)	

te tua(law or government) (l,C,S,O,T)	*Delonix regia* (Boj.) Raf. (R),D	flamboyant, flame tree,poinciana; bin(bean), red tree(Nauru)

W

*te wae(T)(leg); see te banana	*Musa*(AAB Group) Simmonds (R),	plantain,maia F Maoli(Tahiti); vudi,vundi (Fiji); hopa (Tonga)
te wao(L,C,S,O,T)	*Boerhavia repens* L. syn. *B. diffusa* sensu auct. non L. (I)	rabijraka, matok (Marshall Is.)
te wao(C,T); te wao n anti(O); te wao ni anti(S)	*Boerhavia tetrandra* Forst.;, *B. diffusa* L. var. *tetrandra* Forst. f. (I)	

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APPENDIX

The 111 plant species(plus one variety and one hybrid) reportedly present at some time in Kiribati, but which seem to have no recognized local Kiribati vernacular name (The letters L,C,F,O and T refer to those works citing the presence of a given species, with L = Luomala, 1953; C = Calala, 1956; F = Fosberg, Sachet and Oliver, 1979 or 1982, and/or Fosberg and Sachet, 1987; O = Overy, Polunin and Wimblett, 1982; and T = field citation by Thaman, 1985. I = indigenous; A = aboriginal introduction; R = recent post-European contact introduction; D = decorative or ornamental plant; F = food plant; W = weedy species and introduced grasses).

Abutilon asiaticum (L.) Sweet var. albescens (Miq.) Fosb. (F) I
Acalypha hispida Burm.f. (F) R,D
Achyranthes canescens R. Br. (F) I
Adenostemma lanceolatum Miq. (F) R?,W
Adiantum raddianum Presl (C,F) R,D
Agave americana L. (F) R,D
Allamanda hendersonii Bull (C,F,T) R,D
Allamanda violacea Gardiner & Field (T) R,D
Allophylus timoriensis (DC) Bl. (F) I
Alternanthera ficoidea var. bettzickiana (Regel) Backer (F) R,D
Angelonia angustifolia Benth. (C,T) R,D
Angelonia salicariaefolia H. & B. (F) R,D
Annona squamosa L. (T) R,F
Antigonon leptopus H & A (C,F,T) R,D
Apium petroselinum L. (F) R,F
Asclepias curassavica L. (C,F,O) R,D
Asplenium nidus L. (C,F) R,D
Aster laevis L. (F) R,D
Asystasia gangetica (L.) Andres (F,O) R,D
Bacopa monnieri (L.) Wettst. (C,F) I
Basella rubra L. (C,F) R,F
Beta vulgaris L. var cicla L. (T) R,F
Bidens pilosa L. (O,F.T) R,W
Boerhavia albiflora Fosb. (F) I
Brassica oleracea L. var. gongyloides (T) R,F
Breynia disticha J.R. & G. (Forst (T) R,D
Caesalpinia bonduc (L.) Roxb. I
Caladium bicolor (Ait.) Vent (F,O) R,D
Cestrum nocturnum L. (T) R,D
Chicorium endivia L. (C,F) R,F
Clitorea ternatea L. (L,C,F) R,D
Coccoloba uvifera L. (F,O) R,D
Codiaeum variegatum (L.) Bl. (F,O,T) R,D
Conyza bonariensis (L.) Cronq. (F) R,W

Crateva speciosa Volk (F,T) R,F
Crotalaria spectabilis Roth (F,T) R,W
Crotalaria retusa L. (O)? R,W
Curcuma longa L. (F) A?
Cymbopogon citratus (DC.ex Nees) Stapf. (T) R,F
Cynodon dactylon (L.) Pers. (F,T) R,W
Cyperus brevifolius (Rottb.) Hassk. (F) R,W
Cyperus compressus L. (C,F) R,W
Cyperus kyllingia End. (F) R,W
Daucus carota L. (T) (Nees Stapf. (T) R,F
Desmodium heterocarpon (L.) DC. (F) R,W
Desmodium tortuosum (Sw.) DC. (F,O) R, W
Digitaria pacifica Stapf. (F) I?
Digitaria radicosa (J.S. Presl.) Miq. (F) I?
Dracaena deremensis Engler (T) R,D
Dracaena fragrans (L.) Ker-Gawl (T) R,D
Echinochloa crus-galli (L.) Beauv. (F) R,W
Eleocharis acicularis (L.) R. & S. (F) I
Eleutheranthera ruderalis (Sw.) Sch.-Bip (O,T) R,W
Eragrostis whitneyi Fosb. (F) R?,W
Eustachys petraea (Sw.) Desv. (F) R,W
Fagraea berteriana Gray ex Benth. (F) R?,D
Ficus bengalensis L. (F) R,D
Fimbristylis dichotoma (L.) Vahl. I
Gaillardia pulchella Foug. (C,F) R,D
Gliricidia sepium (Jacq.) Steud. (C,F,O,T) R,D
Gloriosa superba L. (F,O,T) R,D
Graptophyllum pictum (L.) Griff. (T) R,D
Hedyotis biflora (L.) Lam. (C,F,O) I?
Hedyotis verticillata (L.) Lam. (F) I
Hemigraphis reptans (Forst.) T. Anders (F) I
Hippaestrum puniceum (Lam.) Urb. (T) R,D
Ixora coccinea L.(C,F) R,D
Kalanchoe tubiflora (Harvey) Hamet (F,T) R,D
Lactuca sativa L. (T) R,F
Lepturus pilgerianus Hans. & Potzt. (F) I?
Licuala grandis H.Wendl. (T) R,D
Melochia odorata L.f.(F) R,W
Mentha piperita L. (F,T) R,F
Momordica charantia L. (T) R,F
Mucuna gigantea Willd. (F) I(drift seed?)
Neisosperma oppositifolia (Lam.) Fosb. & Sachet (F) I
Nephrolepis biserrata (Sw.) Schott (F) I
Oxalis corniculata L. (F) R,W
Passiflora edulis Sims (F,T) R,F
Panicum distachyon L. (F) R,W
Panicum subquadriparum Trin. (F) R,W
Pedilanthus tithymaloides Poiteaa (L.) Poit (O,F,T) R,D
Pennisetum ciliare (L.) Link (F) R,W
Pennisetum polystachion (L.) Schult. (F) R,W
Pennisetum purpureum Schumach. (F) R,W
Pentas lanceolata (Forsk.) DeFlers (F) R,D

Pilea microphylla (L.) Liebm (F,C,O,T) R,W
Plectranthus scuttellariodes (L.) R.Br. (F,O,T) R,D
Pluchea indica (L.) Less. (C,F) R,W
Pluchea x fosbergii Coop. & Gal. (F) R,W
Polygala paniculata L. (F,O,T) R,W
Polyscias filicifolia (Moore) Baily (F,T) R,D
Polyscias grandifolia Volkens (F,O) R,D
Portulaca grandiflora Hook (T) R,D
Prosopis pallida (H. & B.ex Willd.) HBK. (F) R,D
Pteris tripartita Sw. (F,O) I
Pueraria lobata (Willd.) Ohwi (F,O) R,W?
Rhaphanus sativus L. var. sativa (F,T) R,F
Ricinus communis L. (L,C,F,O,T) R,D
Rosa multiflora Thunb. hort. var (F) R,D
Saintpaulia ionantha Wendl. (T) R,D
Setcreasia purpurea B.K. Boom (T) R,D
Sida rhombifolia L. (F,O,T), R,W
Solanum torvum Sw. (F,C) R,W
Spermacoce assurgens R. & P. (F,O.T) R,W
Sporobolis diander (Retz.) Beauv. (F) R,W
Sporobolis fertilis (Steud.) Clayton (F) R,W
Synedrella nodiflora (L.) Gaertn. (C,F,O,.T) R,W
Tamarindus indica L. (C, F) R,F
Tridax procumbens L. (C,F,O) R,W
Vernonia cinerea L. (Less) (L,C.O,F,T) R,W
Zinnia pauciflora L. (F) R,D

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RURUTU RECONSIDERED: THE DEVELOPMENT OF MAKATEA TOPOGRAPHY IN THE AUSTRAL ISLANDS

BY

D. R. STODDART AND T. SPENCER

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BY

D. R. STODDART[1] AND T. SPENCER[2]

ABSTRACT

The islands of the southern Cook and Austral groups in the South Pacific exhibit astonishing differences in geology and topography, even between closely adjacent islands of similar ages. Some are sea-level atolls, others have low fringes of Pleistocene raised reefs, and others substantial rims of elevated mid-Tertiary limestones, locally known as makatea. On some islands the relief of the makatea is subdued, but on others it is dominated by eroded volcanics, sea-level swamps, and vertical limestone walls. Sixty years ago there was great controversy over whether the makatea of Rurutu represented a reef-growth or an erosional topography. Using insights from Mangaia in the southern Cooks we argue that the makatea relief of Rurutu is of erosional origin, and we identify why the Paparai Valley - seen as a key area in the old arguments, even though none of the protagonists had seen it - holds a key to the great inter-island differences which exist in makatea topography in this part of the Pacific.

INTRODUCTION

In 1928, in The Coral Reef Problem, W. M. Davis devoted two chapters of nearly ninety pages - fifteen per cent of the entire book - to the subject of elevated fringing reefs, barrier reefs, almost-atolls and atolls. He clearly believed that the structural relationships with their foundations which elevated reefs revealed had direct significance for theories of reef development, and as a result of his discussion he had little difficulty in persuading himself of the correctness of Darwin's views.

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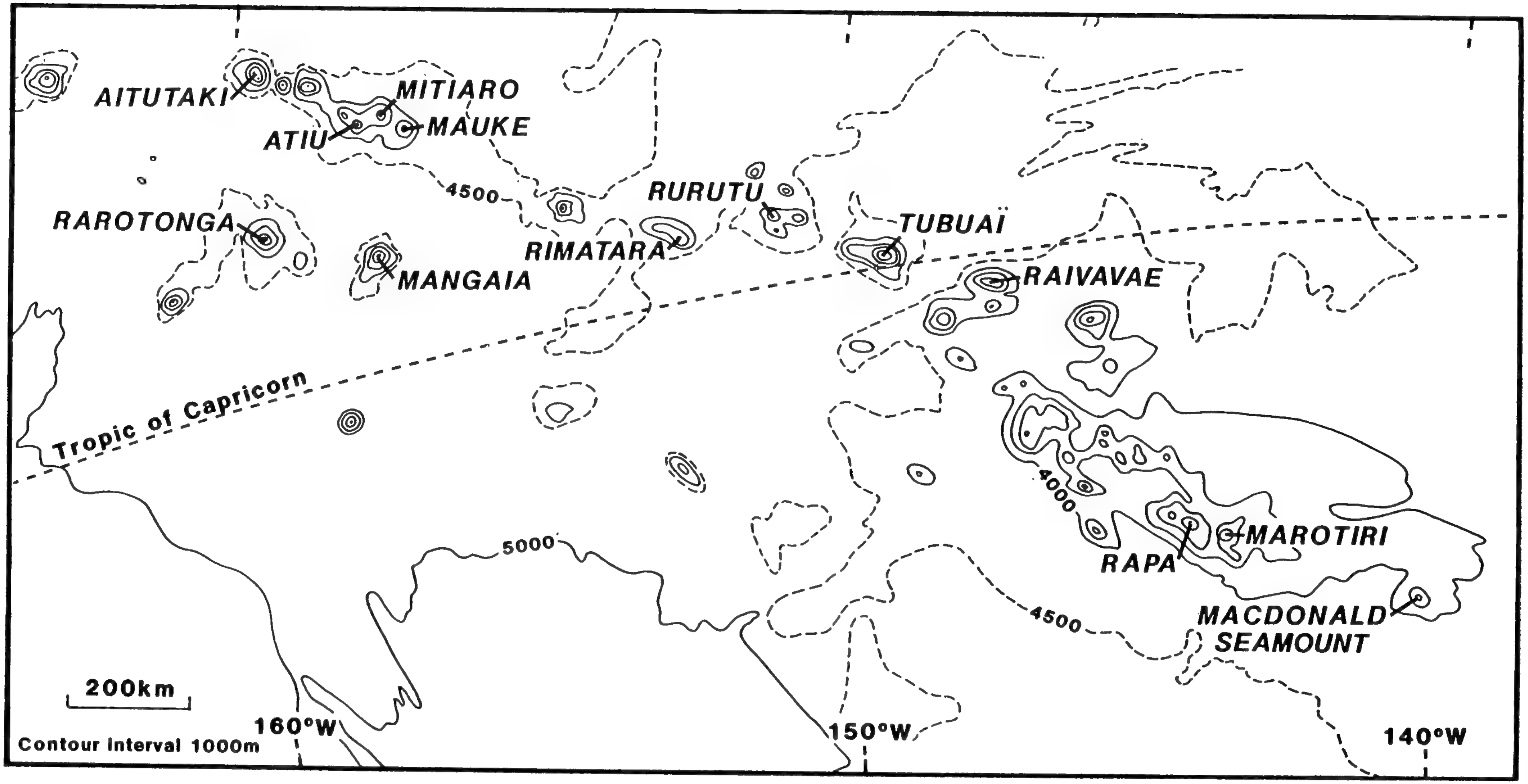

Figure 1. The Southern Cook and Austral Islands

Unfortunately, while he had access to Marshall's (1927) geology of Mangaia in the southern Cooks and to Chubb's (1927a) geology of the Austral Islands, Davis's account predated the great controversy over the significance of raised reefs which developed in the late 1920s and early 1930s, and in particular he did not appreciate the new insights into the erosional development of raised reefs which resulted from the work of H. S. Ladd (1934) in Fiji, J. E. Hoffmeister (1932) in Tonga, and of both in the Lau Archipelago (Ladd and Hoffmeister 1945). These later field studies led to a vigorous renewal of controversy over the coral reef problem in which the conclusions reached differed substantially from those of Davis (Hoffmeister and Ladd 1935, 1944).

Much of this discussion focussed on the reef-capped volcanic islands of Mangaia and Rurutu in southeastern Polynesia. We have recently examined the case of Mangaia (Stoddart, Spencer and Scoffin 1985), and in this paper we reconsider the evidence from Rurutu and comment on other islands in the chain.

Although the volcanoes of the southern Cook and Austral groups are arranged in linear array, broadly increasing in age towards the northwest, the arrangement is far from a simple one (Turner and Jarrard 1982). In the southern Cooks only Mangaia fits the age prediction in terms of plate migration from a hot spot, while Atiu, Mauke and Mitiaro are all substantially younger than predicted. In the Australs actual ages are closer to predicted ages (Figures 1 and 2). Renewed volcanism has also occurred on Aitutaki and Rurutu, substantially later than the initial building of the shielf volcanoes, and broadly coinicdent with the construction of Rarotonga between 2.1 and 1.1 million years B.P.

The most remarkable aspect of the geomorphology of these islands lies in the enormous variability in the development of reefs on them. From southeast to northwest: Marotiri and Rapa have no significant reef development and are indeed extra-tropical; Raivavae and Tubuai have sea-level coral reefs with motus and have no elevated reef limestones (in the case of Tubuai contra Turner and Jarrard 1982, 207); Rurutu and Rimatara have mid-Tertiary reefs elevated to 100 and 11 m respectively; Mangaia has similar reefs believed to be of Oligocene or lower Miocene age, elevated to 70 m; Atiu, Mauke, Mitiaro and Rarotonga have low elevated Pleistocene reefs with (with the exception of Rarotonga) a foundation of Tertiary limestones; and Aitutaki, Takutea and Manuae have no elevated reefs at all, only (like Raivavae and Tubuai) sea-level reefs with motus. The history of these islands has thus clearly been complex in both horizontal and vertical terms (Table 1).

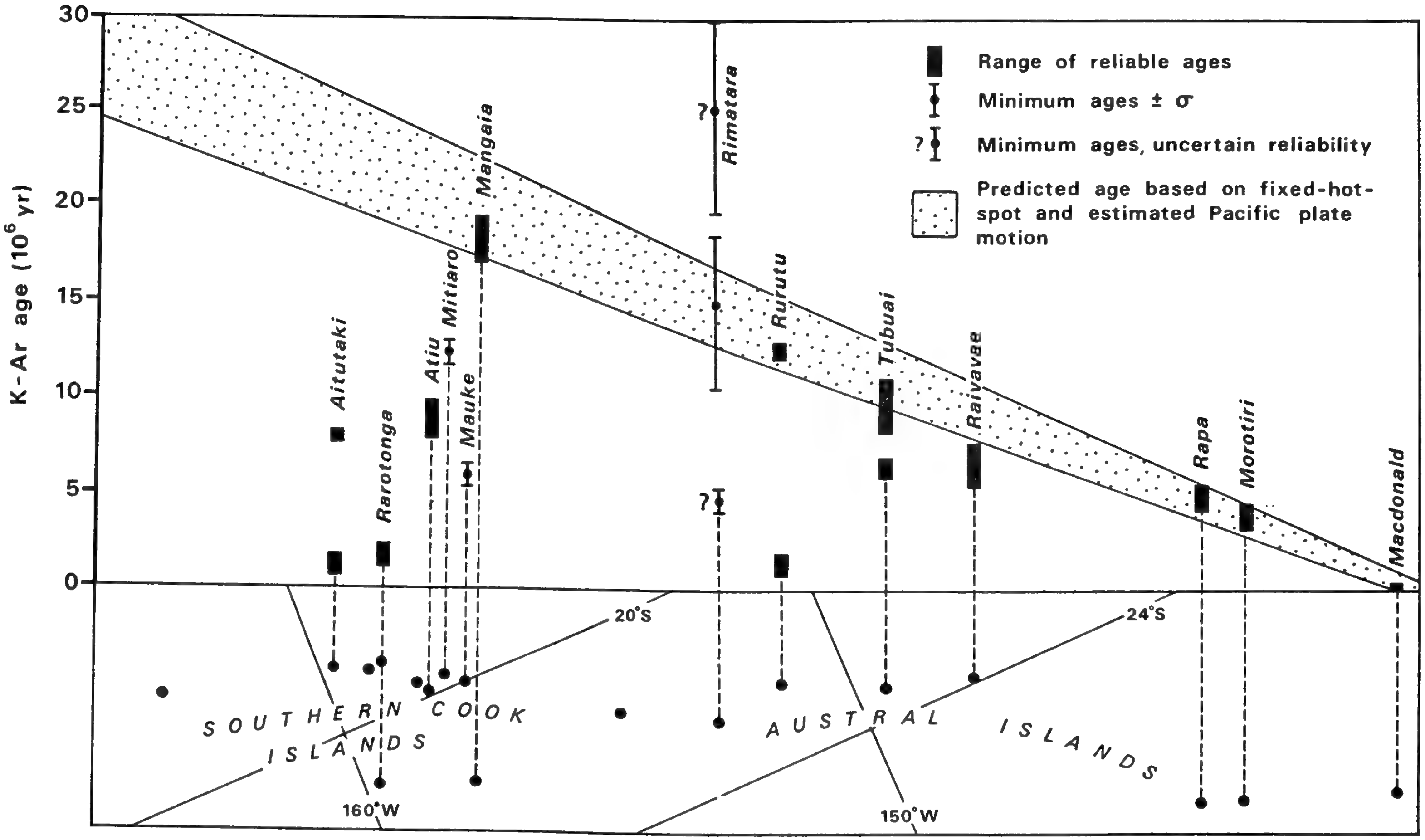

Figure 2. Predicted and actual island age, Southern Cook and Austral Islands chain. Source: Turner and Jarrard (1982), Bellon _et al_ (1980).

Table 1. Age and topography of the Southern Cook and Austral Islands

Island	Age, 10^6 yr	Maximum elevation of volcanics	Maximum elevation of makatea	Maximum elevation of Pleistocene limestones
Rapa	5-5.2	670	nil	nil
Raivavae	5.5-7.4	437	nil	nil
Tubuai	8-10.4	422	nil	nil
Rurutu	12.3 0.6-1.9	389	100	15
Rimatara	>28.6, >21.2 >14.4, >4.8	92	11	?
Mangaia	17.4-19.4	169	73	14.5
Mauke	>6.0	24.4	14.6	10.0
Mitiaro	>12.3	8.9	10.9	9.8
Atiu	8->10	72	22.1	12.2
Rarotonga	>1.6-2.3 1.1-1.4	653	nil	3.5

Sources detailed in text

RURUTU, AUSTRAL ISLANDS

Rurutu is a small volcanic island in the Austral group; it was discovered during Cook's first voyage, though no landing was made. It forms part of a linear chain of volcanoes which extend for 2000 km from the still active Macdonald Seamount in the southeast to the almost-atoll of Aitutaki in the northwest. Rurutu itself extends for 7 km in a north-south direction, and is 1.75-2.4 km wide. The central volcanics have a maximum elevation of 385 m. The island is discontinuously fringed by discrete outcrops of elevated reef limestones, which occupy some 28 per cent of the total area of 32 sq km (Figure 3). The volcanic core consists of submarine basaltic pillow lavas up to 90 m thick at outcrop (the surrounding sea floor is 4-4.5 km deep) (Brousse 1985), dated at 8.6-12.5 million years (Dalrymple et al 1975, Duncan and McDougall 1976, Turner and Jarrard 1982). The pillow laves are discontinuously overlain around the present shoreline by raised reef limestones, dated at late Miocene and up to 100 m thick, with manganiferous clays locally occurring at the contact between the volcanics and the reef deposits. Subsequent to uplift and emergence of the reef limestones there was a renewed phase of subaerial vulcanicity. This formed extensive surface flows dated between 0.6 and 1.1 million years (early Pleistocene). There is a narrow contemporary fringing reef developed in the major bays on the east and west coasts of the island.

The geology of Rurutu was first described by Chubb (1927a) and in greater detail by Obellianne (1955). A summary is given by Bardintzeff, Brousse and Gachon (1985), though the extent and continuity of the makatea limestones is much less than they indicate (compare their Figure 1 and this paper, Figure 3).

THE RURUTU CONTROVERSY

Chubb (1927a, 306) indicated that the elevated limestones of Rurutu 'completely surround the island, except where they are broken through by one of the larger river-valleys', forming a cliffed plateau up to 100 m high. 'Parallel to the south-eastern coast, however, there is a depression, the Paparai valley, running behind the limestone terrace. The drainage down the hillsides reaches the transverse trough, and thence makes its way into the sea by means of caves cut through the base of the limestone' (Chubb 1927a, 306). He inferred a history of episodic uplift of the entire island. He subsequently published (Chubb 1927b) an extended comparison of Mangaia (derived from Marshall 1927) and Rurutu, particularly emphasising the existence at the

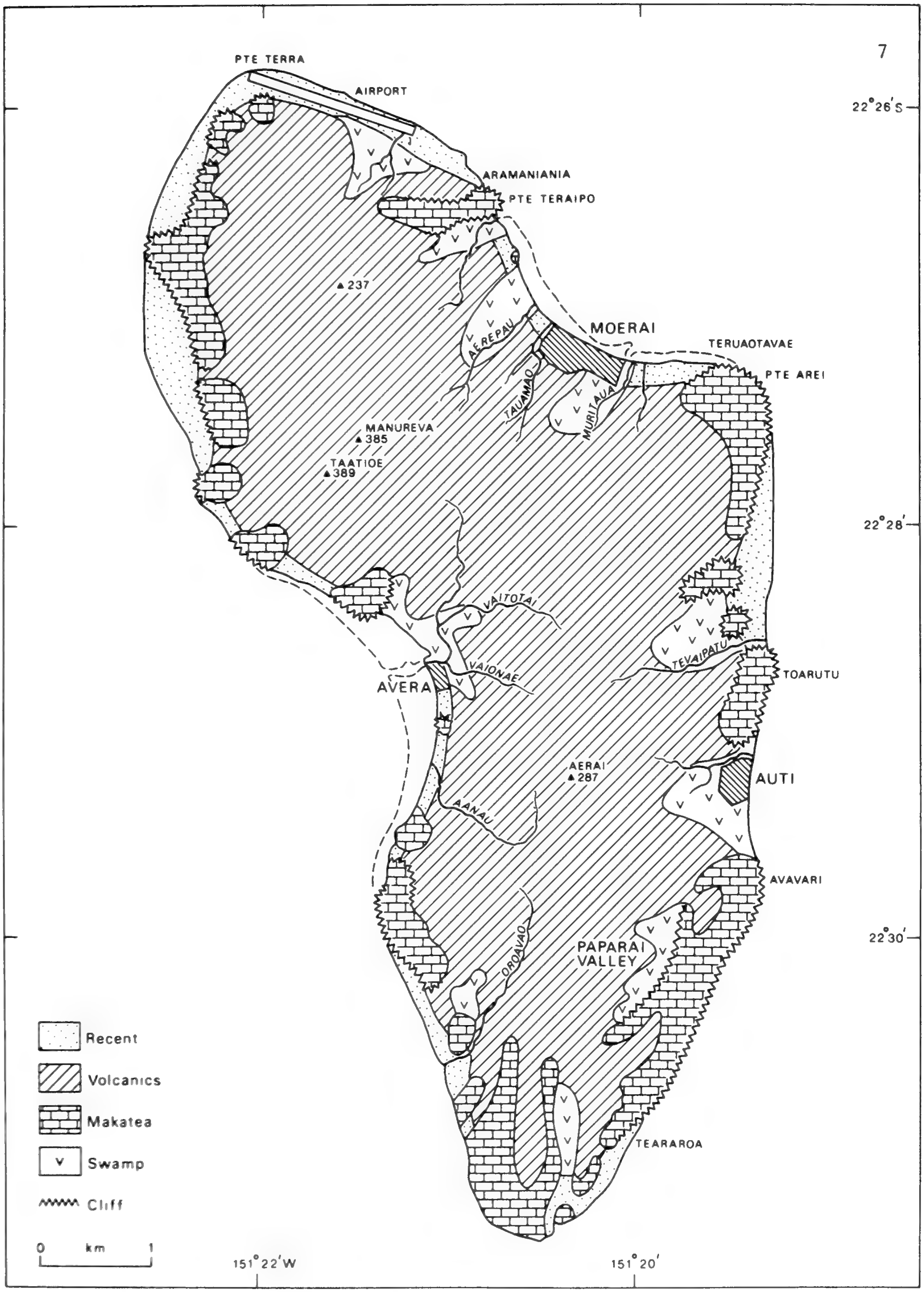

Figure 3. Geology of Rurutu.
Source: Rurutu Carte Touristique (Bureau des Affaires Communales, Moerai, 1977) and sources detailed in text.

former of a swampy depression between the eroded volcanic core and the vertically-cliffed encircling reef limestones. No such depression was found by Chubb at Rurutu, where in the areas seen by him the upper surface of the limestones continued inland to abut the volcanics. The volcanics themselves were drained by streams which flowed seawards on volcanic rocks between the limestone outcrops, rather than, as on Mangaia, through conduits beneath the limestones. Chubb did, however, note the existence on Rurutu of a closed depression, between the limestones and the volcanics, in the Paparai valley, in the southeastern part of the island (Chubb 1927a, 520-521). He suggested that in general the differences between Mangaia and Rurutu could be explained by considering the limestones at Mangaia to have originated as a barrier reef with a lagoon, whereas those at Rurutu had constituted a fringing reef. The depression of the Paparai valley, in spite of its resemblance to the Mangaia swamp depressions, he suggested was the result of subaerial erosion rather than being an inherited barrier-reef lagoon. In summary Chubb believed that the discontinuous nature of the Rurutu makatea resulted from first vertical and then horizontal erosion by surface streams derived from the volcanics, which initially flowed over relatively impermeable limestones and trenched through them. The Paparai valley was formed by subsequent stream development at the contact between the limestone and the volcanics, and Chubb suggested that this process could account in some degree for the Mangaia depressions also.

On the basis of his work at Mangaia and Atiu, Marshall (1929) queried whether the Paparai valley depression could be considered as of subaerial origin, on the grounds of the absence from it of obviously fluvial landforms and sediments and of any undercutting of the makatea slope. He restated his belief that the makatea at Mangaia is a former barrier reef and that at Rurutu a fringing reef, and that their dissimilar modern topographies result from this fundamental difference in origin.

Hoffmeister (1930), from his fieldwork on Eua, considered subaerial erosion a more plausible explanation for the origin of depressions between makatea and volcanics, since few streams are known to flow across limestones or to cut gorges through them, whereas many flow underground at the contact and 'will eventually lead to the formation of a valley lined on one side by the sloping volcanic hills and on the other by a nearly vertical limestone cliff' (1930, 551). But in the case of the critical locality on Rurutu, over which the controversy centred, Hoffmeister cautioned that 'it is true that none of us have seen the Paparai Valley, not even Mr Chubb, who obtained his information second hand' (1930, 550). Neither Marshall nor Hoffmeister, of course, ever visited Rurutu.

There the matter rested. Later French workers such as Obellianne (1955), while adding to geological knowledge, did not discuss the controversy between Marshall, Chubb and Hoffmeister on the origins of the makatea topography, although the importance of karst erosion processes in determining reef morphology became increasingly recognised (Purdy 1974a, 1974b, Stoddart 1973).

EROSIONAL ORIGIN OF MAKATEA TOPOGRAPHY

The main arguments for the erosional origin of makatea topography have been worked out on Mangaia (Stoddart et al 1985) and subsequently on Atiu, Mauke and Mitiaro (Spencer et al 1985). They include:

(a) The aggressive nature of streams draining the volcanics and the fact that these streams drain through discrete conduits in the makatea to reef-flat resurgences. These conduits cannot accommodate flood discharges, so that aggressive waters are dammed back, causing solutional undercutting along the swamp-makatea junction, and ultimately to the formation of a 'karst marginal plain' of the kind often described around tower karst in Central America and Southeast Asia.

(b) This process leads to the slow and episodic retreat of the inner makatea wall. The process may be expected to leave residual outliers, and these are indeed found at Mangaia.

(c) Fluctuations of relative sea-level lead to the relocation of the locus of solutional activity as the swamp-makatea contact is redefined and new conduits and sinkholes develop. There is clear field evidence of this episodic development in abandoned caves and conduits high in makatea walls.

(d) The precise nature of the erosional topography in the Southern Cooks varies with the initial size of the volcanic basement and the consequent geometric constraints on reef development. Thus Mangaia and Atiu have bolder topographies than Mauke and Mitiaro. Uplift history also varies with tectonic context and in particular with arch development around subsequent volcanic loads (McNutt and Menard 1978).

These factors have combined to result in the formation of an extensive depression between volcanics and makatea on Mangaia, and to a lesser extent on Atiu, but not on Mauke (Spencer et al 1985). Thus extensive swamps with high makatea inner walls will only develop where the central volcanos

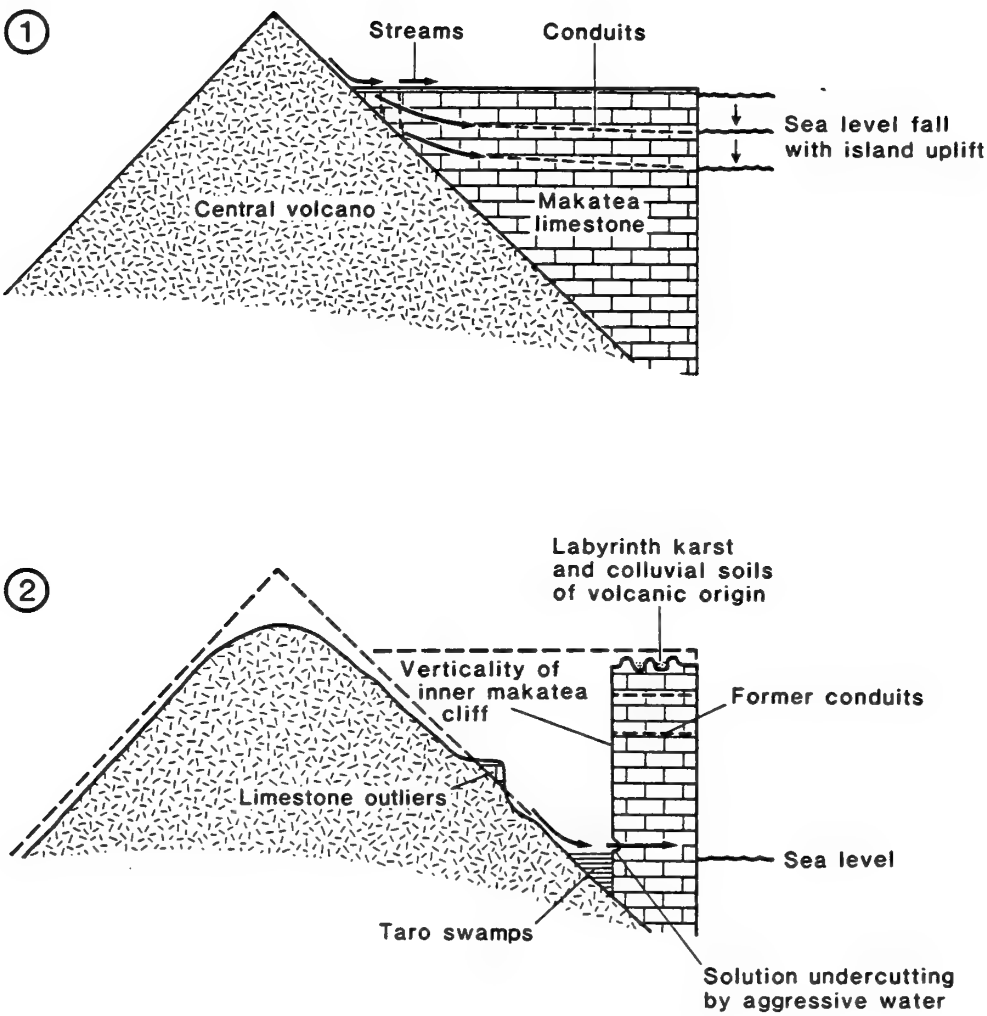

Figure 4. Hypothesis of landform evolution on Mangaia, Cook Islands.

have sufficient area and altitude to deliver enough aggressive water to the swamp-makatea contact. Under these circumstances landforms develop as hypothesized in Figure 4.

THE INDIVIDUALITY OF RURUTU

At first sight the makatea islands of the Australs resemble those of the Southern Cooks. Rimatara in particular repeats the classic pattern of the islands we have just described. Rurutu, however, appears to have had a more complex history. Stratified manganiferous clays occur between the volcanics and the makatea, and the volcanics themselves are identified as submarine pillow lavas. Whereas in the islands of the Southern Cooks the volcanic and reef-building phases were distinct, allowing the development of a complete encircling reef, on Rurutu reef building may have been inhibited by continuing volcanic activity.

The Rurutu makatea now exists as six large (Figure 5) and at least sixteen small separate limestone blocks (Figure 3). Particularly in the northeast the makatea is restricted to the ends of volcanic spurs, and there is, for example, no field evidence that the blocks inland from Pte Teraipo and Pte Arei were ever continuous throug the Moerai lowland.

This has important geomorphological consequences. Whereas on Mangaia drainage from the volcanics is delivered toards the makatea, on Rurutu streams in general drain away from the makatea, located as the latter is on the ends of spurs. There are, of course, some exceptions to this generalisation, for example the southern margin of the block inland from Pte Teraipo (Figure 6), the area immediately north of Auti village, and that northwest of Avera. In all of these locations streams and swamplands abut directly against the makatea and cause solutional undercutting, but this is not a common situation on Rurutu.

As Hoffmeister recognised, the Paparai valley is of particular interest in explaining Rurutu landforms. The valley forms a transverse depression inland from the most laterally-extensive of all the makatea outcrops on the island. In particular this makatea strip terminates to both north and south on prominent volcanic spurs. Unlike any other location on Rurutu, but as generally occurs on Mangaia, aggressive drainage waters are trapped in an enclosed swamp fed by an extensive catchment area on the volcanic slopes to the west. The inner wall of the makatea in the Paparai valley (Figure 7) is an undercut vertical cliff, repeating precisely the common situation at Mangaia (compare Stoddart et al 1985, figure 4). The cliff has clearly retreated by basal solution, and, as at Mangaia, this retreat has left

Figure 5. Isolated makatea block at Toarutu, east coast of Rurutu, seen from the north. Note the prominent seaward depositional dips in the limestones, and the numerous horizontal erosion features (raised intertidal notches and caves) in the vertical limestone wall.

Figure 6. Undercut makatea cliff and swamp depression southwest of Pte Teraipo, Rurutu.

Figure 7. The inner wall of the makatea rim and adjacent swamp depression, Paparai Valley, Rurutu.

behind at least one substantial limestone residual on the west (inland) side of the swamp depression. There is likewise abundant evidence of episodic rejuvenation in the form of raised intertidal notches, horizontal cave horizons, and abandoned drainage conduits in the cliff walls (see Figure 5). The Paparai valley is thus a karst marginal plain identical in origin to those of Mangaia: it owes its existence to the topographically and geologically constrained drainage patterns on the island.

Table 2 gives pH and conductivity measurements on water samples from streams draining the volcanics on Rurutu. Table 3 compares the mean readings for Rurutu streams with those for streams and standing waters on Mangaia, Atiu, Mitiaro and Mauke in the Southern Cooks. Further work on the saturation status of Rurutu waters, to compare with those of the Southern Cooks (Stoddart et al 1985, figure 7) is in progress.

CONCLUSION

We have in this paper outlined the basis for a general theory of erosional development of makatea terrain in Polynesia. We believe that the forms so variably developed on different islands can be readily explained by a consideration of history, geometry and solutional processes, and that we can identify a continuum of forms ranging from low islands of modest relief to the dramatic cliffed terrains of islands like Mangaia.

Marshall was wrong in his diagnosis of Rurutu, and Hoffmeister was right. That the island attracted such controversy more than fifty years ago is perhaps an indication of the critical evidence it affords, most notably in the Paparai valley, of why topography can be so very variable on closely adjacent islands in the south Pacific.

ACKNOWLEDGEMENTS

Our work in Polynesia has been carried out from the start with the staunchest support of Marie-Helene Sachet and F. Raymond Fosberg. Marie-Hélène was with us on Rarotonga when we worked on Mangaia (with T. P. Scoffin) in 1983. We visited Tetiaroa Atoll with her and Dr Fosberg in 1985, and later we went on to Mauke, Mitiaro and Atiu (with C. D. Woodroffe). These studies will be published separately. It was on Tubuai, during our Australs expedition in 1986, that we learned of Marie-Hélène's death. We dedicate this paper to her memory. Fieldwork in the Austral Islands was supported by the Overseas Field Research Grants Board of the Royal Society of London.

Table 2. Water characteristics of streams on Rurutu

Sample number	Location/Stream[1]	pH	Conductivity[2] $\mu S\ cm^{-1}$
1	Pte Toarutu	8.9	262.3
2	R. Tevaipa	7.2	451.3
3	R. Vaioivi	7.6	139.1
4	R. Aerepau	8.3	251.9
5	R. Teaoa	8.0	466.0
6	Paparai Valley	9.0	212.3
7	Paparai Valley	9.2	172.2
8	Paparai Valley	8.5	184.9
9	Paparai Valley	9.4	146.5
10	R. Topea[3]	8.5	1470.1
11	R. Turiarata	8.0	-
12	Vitaria	8.2	267.7
Mean[4]		8.4	255.4

1. Placenames taken from Rurutu Carte Touristique (Bureau des Affaires Communales, Moerai, 1977).
2. Field measurements corrected for cell constant and standardized to 25°C using tables of Golterman *et al* (1978).
3. Brackish: saltwater intrusion.
4. Excluding sample 10.

Table 3. General physical and chemical characteristics of drainage waters in the Southern Cook and Austral Islands

Island (date)	N	pH	Conductivity[1] μ S cm^{-1}	Field temperature °C
Mangaia (2/83)	20	6.8±0.2 (6.4-7.3)	125.7±18.3 (100.7-166.7)	30.6±0.9 (31.8-29.4)
Atiu (6/85)	16	6.7±0.2	430.6±251.9 (139.5±797.3)	
Mitiaro (6/85)	12	7.3±0.7 (6.7-9.0)	24340.3±21154.5 (714.2-44143.9)	
Mauke (6/85)	12	6.4±0.3 (5.8-6.6)	211.3±98.5 (116.8-424.2)	
Rurutu (7/86)	11	8.4±0.7 (7.2-9.4)	255.4±110.6 (139.1-466.0)	

1. Field measurements corrected for cell constant and standardized for 25°C using tables of Golterman *et al* (1978).

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BIOLOGY OF COOK ISLANDS' BIVALVES, PART I. HETERODONT FAMILIES

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BIOLOGY OF COOK ISLANDS' BIVALVES,

PART I. HETERODONT FAMILIES

BY

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INTRODUCTION

The marine invertebrates of the Cook Islands are rather poorly known. Most of our knowledge of them comes from the following sources: the Manihiki Atoll Survey in 1960 (Bullivant & McCann, 1974), the Eclipse Expedition in 1965 (McKnight, 1972), the Cook Bicentennary Expedition in 1969 (Gibbs, 1972; Gibbs et al., 1971; Stoddart & Gibbs, 1975; Stoddart & Pillai, 1972), the Westward Expedition in 1971 (Devaney, 1972, 1974; Devaney & Randall, 1973; Marsh, 1974; Randall, 1978), the NZOI - Royal Society Cook Islands Expedition (Grange & Singleton, 1985, but no studies on invertebrates yet), and a few additional studies (Banner & Banner, 1967; Paulay, 1984, 1985; Scoffin et al., 1985). Significant contributions to knowledge on the Cook Islands bivalve fauna were made by the Manihiki Atoll Survey (McCann, 1974), the Cook Bicentennary Expedition (Gibbs et al., 1975), and the Morgan shell collection of the Rarotonga Museum, a collection consisting primarily of Cook Islands specimens (uncritically listed by Stoddart & Gibbs, 1975). General scientific studies in the Cook Islands have been summarized by Stoddart (1975A).

Since 1982 I have been studying selected marine invertebrates of the Cook Islands in an attempt to understand some of the effects of Pleistocene sea level fluctuations on the marine fauna of Pacific Islands. Among those studied were heterodont bivalves. I selected the Cook Islands and Niue for my studies because they include several tectonically uplifted islands that in many ways mimic conditions presumed to have existed on most Central Pacific Islands during Pleistocene low sea stands.

The purpose of the present study is to: 1/ list the presently known heterodont bivalve fauna of the Cook Islands, 2/ document the habitat specificity of the species involved in as much detail as possible, and 3/ investigate the correlation between a species' habitat specificity and its distribution among the various islands. While several studies have been done on the molluscan fauna of inner reef environments on Pacific islands (though bivalves are often neglected), there has been little work on the fauna of the outer reef slope. An important part of this study involved documenting the bivalve species living on this slope, and thus a large portion of my survey was carried out there.

The Cook Islands are located between Tonga and the islands of French Polynesia. They are more a political than a geographical entity, consisting of 15 islands that are grouped into a widely scattered Northern Group and a more closely set Southern Group. Seven of the 8 islands of the Northern Group are atolls (Penryhn, Pukapuka, Rakahanga, Manihiki, Suwarrow, Palmerston), and 1 (Nassau) is a sand cay. The Southern Group is much more heterogeneous, consisting of one atoll (Manuae), one almost-atoll (Aitutaki),

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one sand cay (Takutea), 4 makatea islands that have a central volcanic core surrounded by uplifted reef facies (Atiu, Mitiaro, Mauke, Mangaia), and one high island with a fringing reef (Rarotonga).

Aspects of the reefal and lagoonar structures of some of the islands have been described in various detail. The morphology of the reefs of Aitutaki has received the greatest attention due to surveys by both the Eclipse and the Cook Bicentenary Expeditions (Stoddart, 1975b; Stoddart & Pillai, 1972; Summerhayes, 1971). Various components of the reefs of Rarotonga have been studied (Gauss, 1982; Lewis et al., 1980; Stoddart & Pillai, 1972), and those of Manihiki were described briefly by Bullivant (1974). The lagoon of Manuae has been described by Summerhayes (1971). Several publications dealing with the geology of the various Cook Islands cover basic reef structure, the principal ones being Marshall (1927), Stoddart, Spencer & Scoffin (1985) and Sugimura et al. (1986) for Mangaia, Marshall (1930) for Atiu and Rarotonga, and Wood & Hay (1970) for the entire group. The ages of the islands are listed by Turner & Jarrard (1982). Stoddart (1975A) reviews the history of the many additional earlier and smaller studies on Cook Island reefs.

Most of the geological and biological research that has been done in the past on the Cook Islands, as well as my own work, has been on islands in the Southern Group. Thus this paper focuses primarily on those islands. Because most bivalve faunal lists are, unfortunately, based largely on poorly-identified specimens, I have chosen to include here only records of specimens that I was able to examine personally. Those species collected by the Cook Bicentennary Expedition from Aitutaki that were not met with during my own survey are discussed, but the records of the Manihiki Survey are not; in the latter case, most identifications are only to the generic level, and those at the species level are questionable. Records from a small collection of bivalves made by G. McCormack on most of the islands of the Northern Cooks are incorporated where appropriate as are holdings from the US National Museum of Natural History (NMNH). The distributions of the species discussed are presented in tables 1 (Southern Cooks) and 2 (Northern Cooks), and their habitat specificities are summarized in table 3. All individual island records for a species are not necessarily listed in the discussion on that species.

ISLANDS AND REEFS STUDIED

I selected three of the Cook islands for detailed study: Aitutaki, Mauke, and Rarotonga, and did some additional but more limited work on Mangaia and Atiu. A brief description of the reef structure relevant to bivalve habitats is summarized below for these 5 islands.

Aitutaki is a triangular (N/SW/SE) almost-atoll, with a large, exceptionally shallow lagoon (max. depth 10.5m, but 75% of it less than 4.5m) (Stoddart, 1975B). The major volcanic island is at the N/NW part of the lagoon, such that it is bordered by a 1-2km wide fringing reef along 2/3 of its NW coast. There are a large number of motus along the E side, while the S and SW reefs are essentially devoid of islets. A brief analysis of the sediments of the Aitutaki lagoon is presented by Summerhayes (1971). Most of the sediments are calcareous with a limited terrestrial component near the main island, and range from a muddy fine sand to a granular coarse sand; granulometric analyses of the sediments are not yet available. The outer reef slope of Aitutaki is the most variable I have seen in the Cook Islands during my studies. In some places (e.g. E of Maungapu), a rather wide shelf slopes very gently to a steep break at a depth of 25-30m, about 200-400m from the reef crest, while in other places (e.g. at several places off the SW reef and

reportedly off the S reef), a sharper dropoff occurs in 8-15m of water, perhaps 50-100m from the crest.

Mauke has a very simple reef system: the entire island is surrounded by a 50-100m wide reef flat, much of which is intertidal and even supratidal but the rest holds up to 3/4m deep water at l;ow tide. On Mauke more than on any other makatea island in the Cook Islands, the reef flat is dominated by a hard reef rock pavement, so that there are few pockets of mobile sediments and few loose rocks under which organisms can shelter. As a result, the fauna of this reef flat is extremely depauparate. The flat is followed seaward by an outer reef slope that slopes gently to a depth of 8-15m, then becomes considerably steeper and extends without interruption to at least 80m. This outer reef slope is generally without shelves, and thus sand and rubble pockets on it are small and few. In one area observed, around and N of Taunganui Landing, there is limited (50m wide) shelf development between 10 and 30m depths with a corresponding increase in soft bottom habitats.

The reefs of the rest of the makatea islands are very similar to that of Mauke with a few differences. Atiu, unlike the other Cook makatea islands but like Niue, has a large stretch of coastline along the N side of the island that lacks a reef flat, the ocean abutting directly against cliff faces. Mangaia has an outer reef slope that steepens precipitously (as on Mauke) but levels off to a wide terrace at perhaps 30-40m depths.

Rarotonga is a classic high island with a fringing reef. The reef increases in size continuously from the SE corner of the island counterclockwise, such that the widest and narrowest reefs are adjacent at the SE corner. The narrowest reefs are the windward E reefs, 50-100m wide with large intertidal portions and large amounts of accumulated rubble. The widest reefs are those on the S side, over 800m wide with a moat that is mostly <1m deep but occasionally reaches depths of up to 3m. The outer reef slope has a 200-600m wide shelf to depths of 26-31m, and then steepens. Limited sediment analyses as well as nearshore bathymetry are presented by Gauss (1982) and Lewis et al. (1980).

The nature of the outer reef slope of an island plays an important role in determining the nature of the bivalve fauna occurring there. On this slope, sediments available for burrowing are generally limited and rather uniform. Steeper outer reefs have fewer potential places for sediments to accumulate, and thus contain fewer and smaller sediment pockets, than do more gently sloping reefs. Where large terraces develop on the outer reef slope, as on Mangaia (or Niue), large amounts of sediment are trapped and extensive habitats for infaunal organisms are created. The various grooves and channels that are cut into a reef in a radiating direction also trap mobile sediments. Although the smaller grooves often have a diversity of sediments as well as fauna, the larger, more open channels often have very uniform sands and are poor in infaunal organisms. Sediment is generally less abundant and coarser in shallow waters (depths <10m) than in deeper waters, especially on steep outer reefs and contains a depauparate fauna.

For the purposes of this paper I distinguish 4 habitat types (Table 3). Three of these are inner reef habitats, the fourth is the outer reef slope. The inner reef habitats overlap to some extent: reef flats (with large intertidal as well as subtidal parts, usually with a hard rock pavement and with water <0.5m deep), moats (mostly subtidal, mostly 0-1m deep, occasionally up to 3m deep, with much mobile sediments) and lagoons (subtidal, with large areas over 3m deep, with much mobile sediments). In a few cases where it was appropriate an outer reef flat habitat was also distinguished. The fourth habitat distinguished is the outer reef slope.

Many of the bivalve species discussed here are known primarily from dead specimens. Hence one may question the validity of the habitat interpretations provided, as post-mortem transport can greatly alter observed distributional patterns. Such transport, however, appears to be of rather limited importance in these islands: there are many species whose valves are found, with rare exception, only on the inner reef or only on the outer reef (eg. see discussion under Fragum fragum, Tellina robusta, Macoma dispar, Asaphis violascens, Gafrarium pectinatum) thus no or only occasional valves were found in habitats where they do not live. Species known only from inner reef habitats are much more common among the heterodonts studied here than species known only from outer reef habitats. In part 2 of this study, however, I will demonstrate the outer-reef specificity of the family Pectinidae; most members of which were found exclusively on the outer reef slope in the Cook Islands.

Post-mortem transport does appear to occur occasionally from outer reef slope to reef flat, especially on windward coasts. I have interpreted specimens found on reef flats as originating from the outer reef when all other data for the given species unequivocally indicate that it is an outer reef specialist.

The specimens here discussed will be (or have already been) deposited in the collections of the Division of Mollusks, NMNH, Smithsonian Institution.

THE FAUNA

CHAMIDAE

Chamids are the only cemented sessile heterodonts in the Cook Islands. Their way of life makes them rather susceptible to ecophenotypic variation, complicating their taxonomy. In addition to the 5 species here reported, at least 2 other species occur, each represented by a single specimen. There are no recent reviews of this family for the area. Bernard's (1976) review of the Eastern Pacific fauna does not include any of the species occurring in the Cooks. Lamy (1927) reviewed the family but without presenting keys, illustrations or sufficient descriptions for many species.

Chama limbula Lamarck, 1819

This species is usually referred to by the name of Chama iostoma Conrad, 1837 or Chama imbricata Broderip, 1835. Lamy (1927) pointed out the synonymy of C. iostoma (described from Hawaii) with Chama limbula, but maintained that C. imbricata was a valid species. Rehder (1980) reported the synonymy of C. iostoma and C. imbricata. Individuals of C. limbula are relatively large; C. pacifica is the only other Chama species of this size in the Cook Islands that I know of but is easily distinguished by the orange color and fine crenulations along the entire inner shell margin.

Chama limbula has been recorded from Suez and E Africa (Lamy, 1927) to the Hawaiian Islands (Kay, 1979) and Easter Island (Rehder, 1980).

Chama limbula is very common on all of the Cook Islands studied, and it supports a minor subsistence fishery. Richard (1985) has studied the growth rates of this species. Chama limbula generally inhabits lagoons and reef flats and often displays different phenotypes in different habitats. On Aitutaki, specimens from the lagoon are larger and have smoother upper valve surfaces than do specimens from shallow subtidal or intertidal reef flats. Further, the valves of the former lack the coarse crenulations found on the posterodorsal inner edge of the valves of the latter. Makatea islands, lacking a lagoon,

have only the latter form. Wherever it occurs, C. limbula is unlike most chamids in living exposed rather than hidden under rocks or in crevices.

Chama limbula is occasionally found on the outer reef slope in shallow (0-15m) water, a habitat it has been collected from on Mauke (BMAK-40) as well as on Niue, but it is mainly restricted to inner reef environments. On Aitutaki it is found in all of the inner reef habitats: on windward reef flats (BAIU-8, 91), in moats (BAIU-3, 11, 22, 80), on outer reef flats (BAIU-27, 59) and in the lagoon (BAIU-9, 151). On Rarotonga it is similarly widespread, most common on windward reef flats (BRAR-88, 89). On all of the makatea islands it is very common on reef flats (BMAK-17, 18, 40, BMNG-4, 5, 6, BATI-1).

Chama pacifica Broderip, 1834

On the basis of NMNH collections, this species is known to occur from Australia and Borneo in the W to the Tuamotu Islands in the E. Specimens found on a ship's hull at Pearl Harbor in Hawaii (NMNH collections) indicate that it has been carried to the Hawaiian Islands as well, though it is not recorded as established there (Kay, 1979).

Chama pacifica appears to be restricted to larger lagoonar habitats. Accordingly, it has been found only on Aitutaki among the Southern Cooks; there I have usually collected it in the lagoon (BAIU-43A, 59, 109), but also once in the moat off the NW part of the main island (BAIU-22). A single specimen from Manihiki in the Northern Cooks, from a lagoon-side beach, is in the NMNH (704419). Among the 28 lots of this species from French Polynesia in the NMNH, all for which habitat data were recorded (20) were collected from lagoons on islands with large lagoons (Tubuai, Tahiti, Bora Bora, Tahaa, Maupiti, Raiatea, Scilly, Rangiroa, Vahitahi, Temoe, Anuanuraro, Raroia, Takume, Gambier).

Chama asperella Lamarck, 1819

This small, variable species has many synonyms and is in need of revision. Its distinction from Chama "spinosa" is somewhat problematic (see discussion under that species). It is recorded from Suez and E Africa in the W to the Tuamotu Islands in the E (Lamy, 1927).

Chama asperella is very common throughout Polynesia in a wide variety of habitats. It is almost invariably cryptic, attached to the undersides of rocks or living in reef crevices. It occurs in inner reef habitats as well as on the outer reef slope.

C. asperella is known from all of the Cook Islands that have been adequately sampled, and presumably exists on the other islands as well. I have collected it from reef flats (BMAK-11, 17, 27, BRAR-59), outer reef flats (BAIU-26, BRAR-42), moats (BAIU-3, 11, 22, 149, BRAR-77, 115, 116), lagoons (BAIU-59, 157), and outer reef slopes (BATI-3, BMAK-32, BRAR-96).

Chama "spinosa" Broderip, 1835 sensu Lamy (1906)

This species and Chama asperella may turn out to be conspecific with further study, a possibility already indicated by Lamy (1927) and Bernard (1976). The name here follows Lamy's (1906) usage for a collection of shells from the Tuamotu and Gambier Islands which are certainly of the same species as the specimens discussed below. In his revision of the family, Lamy (1927) synonymised Chama "spinosa" and C. asperella. Though the

two do appear to overlap to some extent in their characters, they are nevertheless fairly distinct and seem to inhabit rather distinct environments. Chama "spinosa" is predominantly a shallow water (<3m) species, being especially common on exposed reef flats, while C. asperella is much more catholic in its choice of habitat (see above). Morphologically the two differ in that C. "spinosa" has a thicker, more purple shell and tends to have a larger horn-like basal valve than C. asperella. Shell characters do overlap somewhat, however.

On the basis of the NMNH collections, this species is recorded from the Tokelau, Line, Cook, Austral, Society, Gambier, Tuamotu, and Pitcairn Islands.

In the Cooks, Chama "spinosa" was found on all of the islands upon which intensive collections were made, and presumably exists on the others as well. With the exception of one lot from a moat (BAIU-3), all are from reef flats (BMNG-6, BMAK-12, 17, 18, 19, 21, NMNH 721459 & 684517: Rarotonga). Among the NMNH collections from the Cook Islands and further E, this species is invariably recorded from shallow water, either from oceanic reef flats (11 lots), or from the lagoon-side sand flats of atolls (9 lots).

Chama sp. 2

I have not been able to identify this very distinctive species; it is possibly new. It is immediately recognizable by the uniform honeycomb-like sculpture on the exterior of its upper valve and by the yellow internal coloration of its valves. As in many other chamid species, the valves' internal margins are finely crenulated. Chama sp. 2 is at present known to me only from the Niue, Cook, Society, Gambier and Pitcairn Islands.

Nowhere is this species common. It is most frequently found on the outer reef slope (BAIU-82, 131, 133, BRAR-66, 95, 105, BMAK-41, 43), but it also occurs on reef flats (BMAK-19, 21, 39). Two specimens from Tahiti are known from deeper lagoons (BTAH-10, NMNH 766603). I have seen only one live specimen of this species from a reef flat on Niue, and presumably it has a cryptic lifestyle.

LUCINIDAE

The Lucinidae are infaunal filter-feeders, often characteristic of marginal habitats (Bretsky, 1976). The last review of lucinids applicable to the Indo-Pacific region is by Lamy (1920), but it lacks illustrations, keys or sufficient descriptions for identification. The 4 Cook Island species, however, are well known and easily recognized.

Codakia punctata (Linné, 1758)

This species is known from E Africa in the W to the Tuamotu Islands in the E (NMNH collections), and from Hawaii (Kay, 1979). It inhabits mobile sediments, mostly in inner reef environments. Occasional specimens are known from outer reef slopes, but these are much less frequent than are specimens from inner reefs.

In the Cook Islands, Codakia punctata is known only from moats (BAIU-3, 11, 22, 80, BRAR-80, 94, 111, 112) and lagoons (BAIU-7), and is not abundant anywhere. It has not been recorded from any of the very limited reef flats of the makatea islands of the Cooks. On Niue, I have on 3 occasions found specimens of C. punctata on a deep, sandy, rubble terrace 15-33m deep on the outer reef slope. Similarly, one specimen from Raivavae (Austral Is.) in the NMNH (732202) is from 14m on the outer reef slope. Other NMNH specimens of C. punctata from Central Pacific Islands are from a wide range of

habitats, including both outer reef benches and inner reef flats of atoll motus (judging primarily from beach specimens) as well as lagoons.

Codakia tigerina (Linné, 1758)

This species is known from E Africa to the Gambier Islands (NMNH collections). It is the rarer of the two large Codakia species in the Cook Islands. Its habits appear to be rather similar to those of Codakia punctata.

In the Cooks Codakia tigerina is known mostly from moats (BRAR-27, 33, 43, 111), but also occurs on the outer reef slope (BRAR-95, and one record from Niue island). Oddly, it has not yet been recorded from anywhere but Rarotonga and Mangaia among the Cook Islands. The Mangaian specimen (NMNH 365552) bears no habitat information and it may have originated from either the reef flat or the outer reef slope. The few additional specimens in the NMNH with habitat localities and the specimens in my Pacific Islands collections are all from inner reef habitats, mostly from lagoons and from beaches facing lagoons.

Codakia bella (Conrad, 1837)

This species is often referred to as Codakia divergens (Philippi, 1850), a synonym. It is fairly variable in shape and sculpture (see illustrations in Kay, 1979). It has been recorded from Suez in the W (Lamy, 1920), to Hawaii (Kay, 1979) and Easter Island (Rehder, 1980) in the E.

Codakia bella is the most abundant and ubiquitous lucinid in Polynesia. It has been collected on all of the Cook Islands that have been intensively sampled, and presumably occurs on the others also. It is known on these islands from reef flats (BAIU-8, 91, 106, BMAK-16, 21, 35, 42, 70, BMNG-6) where it can live in very limited sand pockets, from outer reef flats (BAIU-128), from moats (BAIU-3, 11, 22, 36, 80, BRAR-24, 28, 31, 53, 111, 112), from lagoons (BAIU-7, 43A, 45, 55, 59, 109, 120, 135, 157, 158) and from outer reef slopes (BAIU-133, 147, BRAR-2, 12, 14, 74, 105, BMAK-20, 23, 29, 32, 34) where it has been collected from depths between 3 and 27m. It is similarly widespread and ubiquitous on other Pacific islands, judging from the NMNH collections.

Anodontia edentula (Linné, 1758)

Several nominal species of Anodontia are very similar to this one. As their shells are very thin and featureless, and as considerable intraspecific variation occurs, a thorough review is needed before the various species can be sorted out. Lamy (1920) has synonymised many of the species already.

Anodontia edentula (dependent on identification) ranges from E Africa to the Tuamotu Islands and Hawaii (NMNH collections). In the Southern Cook Islands it is not particularly common, but, like the other 3 lucinids, inhabits a variety of inner reef as well as outer reef slope habitats. These habitats include moats (BAIU-11, BRAR-24, 43, 94) and lagoons (BAIU-7, 45), and outer reef slopes at depths between 14 and 24m (BAIU-111, 133, BRAR-46, BMAK-23). Specimens from the outer reef slope of Niue were found in 9-33m depths. In French Polynesia this species is often common in well-developed barrier reef and atoll lagoons.

LEPTONACEA

There are several species of leptonaceans in the Cook Island fauna, but are not treated here because the systematics of the group, especially for dead-collected specimens, is in a scattered state.

CARDIIDAE

Cockles are generally shallow-burrowing infaunal bivalves. A few species, including most of the Cook Island forms (Fragum fragum, and probably Fragum mundum and Corculum dionaeum), harbor symbiotic zooxanthellae in their mantle tissues and could thus be depth-limited (Kawaguti, 1950, 1983). Several relevant reviews exist for cardiids (Wilson & Stevenson, 1977; Keen, 1980; Fischer-Piette, 1977), but a review of the family in the entire Indo-Pacific region is needed.

Trachycardium orbitum (Broderip & Sowerby, 1833)

The generic placement of this species is questionable and will depend on future revision of the American species of the genera Trachycardium and Acrosterigma. The former genus has priority if the two are synonyms, but the Indo-Pacific species are more like the American species of Acrosterigma than those of Trachycardium (Wilson & Stevenson, 1977). Trachycardium orbitum is particularly similar to and replaced by Trachycardium angulatum (Lamarck, 1819) to the W.

Trachycardium orbitum is known from the Cook, Austral, Society, Pitcairn, Marquesas (from which the nominal species Trachycardium mendanaense Sowerby, 1897 is described) and Hawaiian islands; it is probably a Central Pacific endemic.

In the Southern Cook Islands Trachycardium orbitum appears to be restricted to outer reef slopes; with the exception of a single valve from a moat beach (BAIU-11) all specimens from the 3 Cook Islands surveyed in detail came from outer reef slopes (BAIU-41, 71, 82, 93, 111, 131, BMAK-9, 46, 71, 73, BRAR-46, 118). There the species had a depth range of 12-52m, and was more common in deeper water. On islands with deeper lagoons like Tahiti T. orbitum is also found in the lagoons. While it is fairly common on the outer reef slopes of many islands, T. orbitum is rarely collected because of its deeper-water habits.

Fragum fragum (Linné, 1758)

This is the most common cockle in the Cook Islands. It ranges throughout the Indo-Pacific from East Africa to the Tuamotu Islands. On some islands, e.g. many Tuamotu atolls, it is exceedingly abundant. Richard (1983) studied the productivity of this species in the lagoon of Anaa Atoll (Tuamotu Is.). Kawaguti (1983) showed that this species has symbiotic zooxanthellae, which may explain in part its restriction to mostly shallow water: among over 100 lots of Fragum fragum specimens at the NMNH, one is from18-27m (NMNH 789653: Rangiroa lagoon) and all others are from <18m depths. All of the 39 lots in my collections are from <18m depths.

Fragum fragum is unknown to me from the outer reef slope. Its absence from the outer reef slope of islands on which it is otherwise very abundant is an indication of the relative unimportance of post-mortem transport from inner to outer reef. It is generally absent from reef flats as well as from outer reefs; the only reef flat specimens I know of are one record from Mangaia (NMNH 365553) and 3 from outer motu beaches in the Tuamotu Islands (NMNH 698064, 723199, 723693, compared to many records from inner motu beaches on these islands). Thus F. fragum is very rare or absent on makatea

islands, which have only reef flats and outer reef slopes to offer. It is abundant in moats (BAIU-3, 11, 12, 22, 39, 80, BRAR-24, 30, 31, 40, 52, 111, 112 and many other locations not recorded) and in lagoons (BAIU-7, 43A, 45, 46, 59, 109, 114, 118, 134, 157, 158).

Fragum unedo (Linné, 1758)

This species was recorded from Aitutaki by the Cook Bicentennary Expedition (Gibbs et al., 1975) from 2 localities in the lagoon. Since Fragum unedo is not known E of Samoa and was not collected by me in 1986, one lot of specimens from the Cook Bicentennary Expedition collections at the National Museum of New Zealand (Wellington) was borrowed through the courtesy of B.A. Marshall to ascertain its identity. The 3 specimens in the lot (MF-21699) are all juvenile Fragum fragum, thus there is no evidence for the existence of F. unedo in the Cook Islands at present.

Fragum mundum (Reeve, 1845)

Fragum mundum is a small species, <1cm in size. It is somewhat similar to F. fragum but is easily distinguished by its drawn-out posteroventral angle and its much smaller size. It has a patchy record, partly because it is easily overlooked but also because it is apparently rare over much of its range. On certain islands, however, such as Raroia (Tuamotu Is.), it can be very abundant, contributing substantially to beach sand formation. Fragum mundum was described from S Marutea in the Tuamotus and is known from several islands in the Tuamotus, Cooks, Marshalls, and Samoa (NMNH collections), from Kapingamarangi (NMNH), from Niue (my collections), Hawaii (Kay, 1979), Queensland, and Japan (Fischer-Piette, 1977).

Kay (1979) notes this species to be "common in shallow water, occurring singly nestling in the algal-sand mat of tide pools and shoreward fringing reefs". Considering its shallow habit and close relationship to Fragum fragum and Fragum unedo, both of which are known to harbor zooxanthellae (Kawaguti, 1983), it is possible that Fragum mundum does likewise.

The single record from the Cook Islands is from the shallow lagoon side of a motu on Suwarrow Atoll (NMNH 704506: E side of Anchorage, W side of Pylades Bay, 6. XI. 1973, coll. H.A. Rehder). The abundant NMNH collections (29 lots) from Raroia are all from depths ≤3m; most are from the oceanic reef flat, but some are from the lagoonar sides of motus.

Corculum dionaeum (Broderip & Sowerby, 1828)

The genus Corculum was revised by Bartsch (1947) and includes only this species in Southeastern Polynesia. The range of Corculum dionaeum as recorded by Bartsch (1947) is rather limited: Anaa (Tuamotu Is.), Tuamotu, Mangaia (Cook Is.), and Lifu (Loyalty Is.). Records at the NMNH since Bartsch's paper include ones from Tubuai (Austral Is.) (705443), Tetiaroa (Society Is.) (706004, 705904), Takume (723692), Temoe (671843) Takaroa (790057) and Raroia (720623 and 13 other lots), these last 4 islands are all in the Tuamotus. In addition, Fischer-Piette (1977) records it (as Corculum cardissa, in the synonymy of which he includes all Corculum species) from Gambier. This species is thus known mostly from Southeastern Polynesia, with an isolated record from Lifu in the Loyalty Islands.

Corculum dionaeum appears to live almost exclusively on seaward reef flats, though it may also inhabit shallow lagoonar flats. Corculum cardissa was shown to harbor zooxanthellae by Kawaguti (1950), and it is likely that all species in the genus do so; the form of their shells seems to be adapted specifically toward this end.

My 2 records from the Cook Islands (BAIU-91, BMAK-35) are from beaches behind seaward reef flats. A third record (NMNH 363437: Mangaia) is probably from a similar setting, as Mangaia has only reef flats and outer reefs. All of the lots of Corculum dionaeum specimens at the NMNH are from ocean or lagoon beaches of atolls with 2 exceptions, both of which were dead-collected from lagoons in 0-3m depths.

TRIDACNIDAE

There are 2 indigenous species of giant clams in the Cook Islands. A third species, Tridacna derasa, has been recently introduced by the Cook Islands Fisheries Department to Aitutaki. The tridacnids are a small family of only 7 species. Six species were reviewed by Rosewater (1965), since then an additional species of Hippopus was described (Rosewater, 1982).

Tridacna maxima (Röding, 1798)

Tridacna maxima ranges from E Africa (Rosewater, 1965) to Ducie Atoll (Pitcairn group) (NMNH). It is generally a conspicuous and abundant species on all hard-substrate reef environments where it occurs. Richard (1977) studied its growth and abundance in the Takapoto lagoon (Tuamotu). It is strongly byssate and is generally partly buried in reef material, making it difficult to dislodge.

In the Cook Islands, it is common on reef flats (BAIU-8, 91, 106, BMAK-12, 17, 18), moats (BAIU-3, 11, 22, 80, BRAR-111, 112), outer reef flats (BAIU-24), lagoons (BAIU-59, 109) and outer reef slopes (BAIU-131). The small number of records presented here reflects only the small number of collections; this species is in fact found very commonly in all of these habitats. It is hard to judge which habitats it favors most because it suffers from very heavy fishing pressure; the species forms the basis of an important local subsistance fishery, especially on Aitutaki. The largest concentrations of it are on various patch reefs in the Aitutaki lagoon today. It is not common on the outer reef slope, a habitat which, due to its depth, is not heavily fished.Tridacna maxima is widespread on all of the islands I sampled, but it is more abundant on islands with larger inner reefs, especially Aitutaki.

Tridacna squamosa Lamarck, 1819

Until now Tridacna squamosa was known only from E Africa to Samoa and Tonga (Rosewater, 1965). It is in fact widespread in the Cook Islands, though not common, and recently I found it in abundance on the outer reef slope of Ducie Atoll (Pitcairn Islands), thus extending the geographic range toward the E as far as that of Tridacna maxima.

Tridacna squamosa is unattached or weakly attached by byssus as an adult and nestles in rubble or in reef pockets. All specimens found in the Cook Islands were from the outer reef slope (BAIU-82, BMAK-74, BRAR-62, 119) where it is occasionally encountered to depths of at least 30m.

TELLINIDAE

Tellinids are the most diverse group of heterodonts in the Cook Islands. They are mostly infaunal deposit feeders and several species appear to be restricted to inner reef or lagoonar environments. There are no recent reviews of the Indo-Pacific fauna, but Boss' (1969) treatment of the South African Tellininae covers some widespread Indo-Pacific species, and Afshar (1969) reviewed the generic and subgeneric classification of the family.

Tellina (Tellinella) virgata Linné, 1758

Boss (1969) presents a thorough discussion of Tellinella species, including Tellina virgata. Tellina virgata ranges from S. Africa in the W (Boss, 1969) to the Tuamotu Islands in the E (NMNH collections). Boss (1969) describes it as a "common shallow water species that prefers sandy substrates".

In Southeastern Polynesia, Tellina virgata appears to be strictly an inhabitant of inner reef environments, especially lagoons. It is known only from islands with well-developed barrier reefs and from atolls: Aitutaki, Tahiti, Moorea, Bora Bora, Tikahau (Tuamotu Is.), Rangiroa (Tuamotu Is.), and Gambier (NMNH and personal records). Among the Southern Cook Islands it has been recorded, as might be expected considering its habitat requirements, only from Aitutaki. There it has been collected from the moat (BAIU-3) and from the lagoon (BAIU-43A, 45, 109), but it is uncommon.

All of the 7 lots of specimens from the Society and Tuamotu Islands with habitat information in the NMNH were dredged from lagoons at 9-29m depths; the single Gambier collection is a beach specimen. Three of the 4 lots that I collected in the Society Islands are from 0-2m depths on sand flats, and one is from 15-18m in a lagoonar bay.

Tellina (Tellinella) staurella Lamarck, 1818

This species was recorded from Aitutaki by the Cook Bicentennary Expedition (Gibbs, Vevers, & Stoddart, 1975) from 7 stations in the lagoon, making it the second most common bivalve collected by the expedition. Considering that Tellina staurella is not known E of Samoa, that I did not find the species on Aitutaki (an unusual circumstance if it indeed was so abundant only 17 years ago), and that there are no records of it at the NMNH, it is likely that the specimens collected by the expedition were misidentified. There is no material with this identification in the holdings of the National Museum of New Zealand where the mollusc collections of the Cook Bicentennary Expeditions were supposed to have been deposited (B.A. Marshall, personal communication). I hypothesize that the specimens originally identified as T. staurella were actually Loxoglypta rhomboides, the only tellinid species resembling T. staurella that occurs in such abundance in Aitutaki's lagoon. Accordingly, L. rhomboides was not recorded by the Expedition. The other 2 Tellinella species, Tellina virgata and Tellina crucigera, are both uncommon in Aitutaki.

Tellina (Tellinella) crucigera Lamarck, 1818

Tellina tithonia Gould is synonymous with Tellina crucigera. This species is widespread from E Africa to Hawaii (Kay, 1979) and to the Tuamotu and Gambier Islands (NMNH collections). It can be distinguished from the related Tellina virgata and Tellina staurella by its dorsoventrally shallower shell, a more posterior umbo, and the absence or very poor development of the ventral process of the posterior adductor muscle scar.

Some specimens are only tentatively included under this identification (BAIU-130, 133), as they appear to be intermediate between Tellina crucigera and Tellina rastellum: they have the shape and size of the former, but the localized rasplike sculpture that is characteristic of the latter. I know of 4 lots of specimens of this morph: 1 from Niue, 1 from Temoe, Tuamotus (NMNH 731473), and the 2 from Aitutaki. All are very similar and all are from the outer reef slope.

Kay (1979) notes this species to be most common in depths of 8-100m. In Southeastern Polynesia it appears to inhabit both inner and outer reef environments. In the Cook Islands it is known from moats (BAIU-3, 22, BRAR-86), from a deep passage through a fringing reef (BRAR-93), and from the outer reef slope (BAIU-79; and the specimens with rasplike sculpture BAIU-130, 133). I have collected 3 specimens of this species from the outer reef slope of Niue, one with the rasplike shell sculpture discussed. The limited collections at the NMNH from Southeastern Polynesia are mostly beach specimens, but 6 lots are from lagoons and the single specimen with rasplike sculpture referred to above (731473) is from the outer reef slope. The depth range of these specimens is 18-27m in lagoonar areas (NMNH 789634: Rangiroa, Tuamotu Is.), and up to 41m on the outer reef slope (NMNH 731473: Temoe, Tuamotu Is.).

Tellina (Quidnipagus) palatam (Iredale, 1929)

This species is the only one in the subgenus Quidnipagus and it is readily recognizable. It ranges from Africa to the Tuamotu and Hawaiian Islands (Boss, 1969).

Boss (1969) notes that Tellina palatam "lives in rather shallow water in coarse substrates", while Kay (1979) writes that "these bivalves are found in silty sand inshore on fringing reefs and at depths of 2 to 3m." Except for a few dead specimens collected at depths to 10-15m (Tahiti, my collections), this species was found exclusively in very shallow water. It has a patchy distribution, but can be locally abundant. For example, on Rarotonga, a particularly large assemblage of dead shells was found at <0.5m depth on a small landward embayment of Oneroa Motu.

In the Cook Islands Tellina palatam is widespread and is most often found on moats (BAIU-3, 11, 22, BRAR-24, 27, 94, 111, 112), and in shallow lagoons (BAIU-7, 43A, 109). The single Mangaian specimen (NMNH 613405) is the only one from a makatea island; it is without habitat data, but is presumably from the reef flat. No records exist for this species from any other makatea island nor from any outer reef slopes. All NMNH habitat records (21 lots) of this species from Southeastern Polynesia are from shallow inner reef environments.

Tellina (Arcopagia) scobinata Linné, 1758

The genus/subgenus of this readily recognizeable species is often referred to as Scutarcopagia or as various combinations of Tellina, Arcopagia, and Scutarcopagia. The present generic/subgeneric assignment follows Boss (1969). The species ranges from E Africa to the Tuamotu Islands and to Henderson Island in the Pitcairn group (NMNH collections); in Hawaii it is replaced by the dubiously distinct Tellina elizabethae Pilsbry, its only close relative (Kay, 1979).

Tellina scobinata is a very common species, probably found on most if not all islands in the Cooks and in the rest of Polynesia. It occurs in a variety of habitats, usually burrowing in coarse substrates and sometimes nestling partly exposed in rubble. It has been collected on reef flats (BAIU-8, 91, BRAR-71, 90, BMNG-6), outer reef flats

(BAIU-24, 152), moats (BAIU-3, 11, 22, 80, BRAR-24, 31, 111, 112), lagoons (BAIU-7, 43A, 59, 109, 158) and on the outer reef slope (BAIU-41, 71, 79, 82, 130, 131, 133, 147, BRAR-2, 21, 46, 105, BMAK-9, 31, 36) at depths between 10 and 30m.

Tellina (Arcopagia) robusta Hanley, 1844

The genus of the species group to which Tellina robusta belongs is sometimes referred to as Arcopagia (Pinguitellina) or as other combinations of Tellina, Arcopagia, and Pinguitellina. The present classification follows Boss (1969). Tellina robusta has many close relatives and in the Society Islands a related species, Tellina ?nux Hanley also occurs commonly. Tellina robusta ranges from E Africa to Hawaii (Kay, 1979) and to the Tuamotu Islands (NMNH collections).

Tellina robusta is a strictly inner reef species, occuring only in moats and lagoons. Accordingly it is not known from any makatea islands. It is very common in moats and lagoons, and it was this bivalve species that was recovered from the largest number of lagoon stations on Aitutaki by the Cook Bicentennary Expedition. My records for T. robusta include moats (BAIU-3, 4, 11, 12, 22, BRAR-31, 33, 111), outer reef flats (BAIU-29) and lagoons (BAIU-7, 43A, 45, 59, 109, 114, 118, 120, 121, 124, 134, 135, 157, 158). The NMNH records for this species from Southeastern Polynesia are also entirely inner reef, from barrier reef islands or atolls in the Society, Austral and Tuamotu groups. Among the NMNH collections, the greatest depth recorded for the species is 23-29m, from the lagoon of Bora Bora (Society Is.) (NMNH 629920).

Tellina (Cadella) semen Hanley, 1844

This small species ranges from Africa (Boss, 1969) to the Tuamotu and Gambier Islands (NMNH collections); in Hawaii it is replaced by the similar and probably synonymous Tellina oahuana (Dall, Bartsch & Rehder). Tellina mauia (Dall, Bartsch & Rehder) is synonymised under T. oahuana by Kay (1979) and Burch & Burch (1981) demonstrated that the 2 forms in Hawaii intergrade completely. Rehder (1980) recorded T. mauia from Easter Island and noted T. oahuana proper to be the French Polynesian species.

Boss (1969) writes: "Tellina semen lives in offshore waters, usually in relatively coarse substrates..... Maes (1967) noted that this species was abundant at Cocos-Keeling in fine, soft sand in shallow water. It was not an intertidal or beach species and rapidly buried itself in the substrate if disturbed." Tellina oahuana was found from 10 to 75 fathoms and noted to be one of the most abundant bivalves in Hawaii by Burch & Burch (1981). The present collections indicate that this species lives both in outer reef and inner reef habitats.

There are only 3 records of the species in the Cook Islands at present: 1 from a moat (BAIU-39) and 2 from the outer reef slope (BRAR-105, BMAK-69). An additional outer reef slope specimen is known from Niue. There are 12 lots at the NMNH from Raroia (Tuamotu Is.), all from the lagoon, from beaches to 17m depths. The 5 NMNH lots from the Society Islands are also from lagoons, from beaches to 15m depths, and the single Gambier lot is from a lagoon beach. I found this species to be common (6 lots) in Paopao Bay as well as elsewhere in the lagoon on Moorea (Society Is.), at 1-18m depths.

Jactellina obliquaria (Deshayes, 1854)

This small, yellow, scissulate species, described from "the Pacific Ocean", is widespread in the Pacific, with specimens from the Marshall, Gilbert, Fiji, Niue, Cook, Society, Tuamotu, and Gambier Islands in the NMNH and my collections.

Jactellina obliquaria is known in the Cook Islands from reef flats (NMNH 697320, 697291: both from Aitutaki, ocean-side beach of Akaiami motu), outer reef flats (BAIU-128), moats (BRAR-43), lagoons (BAIU-59) and outer reef slopes (BAIU-130), but nowhere is it abundant. It is known from the outer reef slope of Niue (2 records). The combined depth range of the outer reef records (1 from the Cook Islands and 2 from Niue) is 12-19m. This species is common in inner reef environments in the Society Islands, most often in shallow water (0-2m), but also at depths to 16-18m in lagoons (personal observation).

Loxoglypta rhomboides (Quoy & Gaimard, 1834)

This species is sometimes referred to as Tellina rhomboides, but it belongs to the Macominae, not to the Tellininae. It extends from E Africa (Boss, 1969) to Oeno Atoll (Pitcairn Group) (NMNH collections). The similar, and possibly synonymous Loxoglypta obliquilineata (Conrad, 1837) is known from Hawaii.

Loxoglypta rhomboides is a very abundant and ubiquitous species, occurring in a variety of habitats but especially abundant in inner reef environments. In the Cook Islands it is known from moats (BAIU-3, 4, 11, 22, 51, BRAR-24, 31, 43, 86, 111), lagoons (BAIU-7, 43A, 109, 114, 120, 125, 135, 157, 158), and outer reef slopes (BAIU-130, 133, BRAR-46, 105, BMAK-34, 38). Among these habitats, it is most common in lagoons and least common on the outer reef slope. Accordingly, among the Southern Cook islands this species is most abundant on Aitutaki and least abundant on the makatea islands (only 4 individuals are known from Mauke). In the Society and Tuamotu Islands L. rhomboides is very common in the various inner reef environments (over 50 lots at NMNH). Two presumably outer reef slope records exist for Anaa (NMNH 775883, 775884: Tuamotu Is., off NE Pt. diving, 60 feet). Probably due to its diverse habits, L. rhomboides is known from all islands within its range that have been intensively sampled, and it is probably present on the others as well. Presumably the specimens identified as Tellina staurella in the Cook Bicentenary Expedition collections were of this species (See discussion under T. staurella).

Macoma (Scissulina) dispar (Conrad, 1837)

This species, again of the Macominae, is often referred to as Tellina dispar. Boss (1969) treats it extensively. It ranges from Africa to Hawaii (Boss, 1969) and to the Tuamotu Islands (NMNH collections).

Boss (1969) notes that Macoma dispar lives "from below the low tide zone to depths of up to 10 fathoms", especially in "calcareous sandy bottoms with a relatively coarse texture." In Southeastern Polynesia it is known only from islands with barrier reefs and from atolls, and it appears to be almost entirely restricted to lagoons.

In the Cook Islands it is known from Aitutaki and Rakahanga. With the exception of 1 specimen from an outer reef flat (BAIU-29), it was found only in the lagoon on Aitutaki (BAIU-7, 43A, 109, 114, 125, 157, 158), where it was very common. The 20 records I know of (NMNH and my collections) from French Polynesia are all from lagoons or shallow inner sand flats, with the exception of a single valve from the oceanside beach and inner reef flat of Tetiaroa Atoll (NMNH 705716). Again, the absence of specimens of

this species from the outer reef slope in spite of its abundance in the lagoon is an indication of minimal post-mortem transport from inner to outer reef.

PSAMMOBIIDAE

Gari gari (Linné, 1758)

This species was recorded from 3 lagoon stations by the Cook Bicentennary Expedition in Aitutaki. Gari gari is a nomen nudum (Dodge, 1952). I have not found any Gari species in the Cook Islands, though Gari ?pennata (Deshayes) is known from Tahiti and Niue. There are no specimens with this identification deposited in the National Museum of New Zealand, where the molluscan collections of the Cook Bicentennary Expedition were supposed to have been deposited (B.A. Marshall, personal; communication). The identity of this species thus remains unresolved.

Asaphis violascens (Forsskål, 1775)

The only species of its genus in the Pacific, Asaphis violascens ranges from E Africa to the Tuamotu-Gambier Islands and is considered conspecific by some authors with the Atlantic Asaphis deflorata (Linné, 1758) which, in that case, has priority. In several publications dealing with Polynesian shells the erroneous spelling A. violaceus appears. In the Cook Islands the species is the basis of a minor subsistence fishery on Rarotonga and Aitutaki at least.

Asaphis violascens is a deeply burrowing, strictly very shallow water, mostly intertidal species. Kira (1962) notes that it is "very common on muddy and gravelly bottoms near the low tide mark." Among the over 60 lots from Southeastern Polynesia at the NMNH, the greatest depth from which this species is recorded is 2m (dead). Asaphis violascens is least common on makatea islands, presumably due to the rarity of low intertidal mobile sediments on these islands.

Most records of the species are from moat and lagoon shores (BAIU-3, 7, 8, 11, 22, 43A, 80, 91, 109, BMAK-19, 39, BRAR-111, 112) with only a few specimens (all dead) from moats (BRAR-27, 31) and one from the outer reef slope in front of the principal harbor of Rarotonga (BRAR-27, dead). Within its shoreside habitat, Asaphis violascens is patchily distributed. On Aitutaki, the S ends (channel side) of at least 2 of the E side motus (Akaiami and Papau) have large populations of these clams in poorly sorted rubbly sediments.

SEMELIDAE

Semelids are infaunal deposit feeders, and while they are not abundant numerically in the Cook Islands, at least 5 species occur there (one of which is represented only by a small fragment and is not included here).

Semele australis (Sowerby, 1832)

Described from S Marutea (Tuamotu Is.), Semele australis ranges at least to Hawaii (Kay, 1979), Easter Island (Rehder, 1980), Loyalty Islands (NMNH collections) and Ryukyu Islands (Habe, 1964). It appears to frequent shallow inner reef environments as well as deeper outer reef waters. Kay notes that in Hawaii it inhabits shallow waters.

It was found on all of the Cook Islands intensively surveyed and probably inhabits the others as well. Records are from outer reef flats (BAIU-24), reef flats (BAIU-91, BMAK-19, 39, 42), moats (BAIU-4, BRAR-111, 114), lagoons (BAIU-45, 59), and outer reef slopes (BAIU-131, 133, BRAR-105). Among the NMNH collections from Southeastern Polynesia most specimens come from beach drift or shallow depths (<2m). Occasional specimens, all from the reef-poor Marquesas and Rapa Islands, come from greater depths (3 lots: 3-18m, 1 lot: a single valve from 108-121m). There are no records of this species from the lagoonar dredging surveys in the Society and Tuamotu Islands, though I have found valves at 15-18m in the lagoonar Paopao Bay of Moorea. The greatest depth at which this species was collected in the Cook Islands is 19-21m (BAIU-133).

Abra seurati (Lamy, 1906)

Described from Anaa (Tuamotu), Abra seurati is known from the Fiji, Niue, Cook, Austral, Society, Tuamotu and Gambier Islands (NMNH and personal collections), from a total of only 23 lots of specimens. The largest number of specimens (9 lots) are from Aitutaki, where it was usually encountered singly. It appears to occupy a variety of reef environments.

In the Cook Islands it is known only from Aitutaki and Rarotonga, from the following habitats: moats (BAIU-44A, 51), lagoons (BAIU-43A, 59, 125, 135, 158), outer reef flats (BAIU-106), and outer reef slopes (BAIU-131, BRAR-105). There is one record of Abra seurati from the outer reef slope of Niue, 2 records from 2-9m on shoreside lagoonar sandy bottoms in Fiji, 1 record from 15-18m in the lagoonar Paopao Bay of Moorea, 1 record from just behind a barrier reef crest on Tahiti, and 2 records from lagoons (1 from 17m) in the Tuamotus. All remaining records of the species are beach specimens from islands surrounded by barrier reef lagoons.

Lonoa hawaiiensis Dall, Bartsch & Rehder, 1938

To date Lonoa hawaiiensis was known only from Hawaii (Kay, 1979). I collected single specimens of it from 3 additional localities: Tahiti, Aitutaki (BAIU-74), and Niue. All 3 specimens are from the outer reef slope at 8-27m depths, and all were found dead. The Niue specimen (complete with both valves) was found nestled within the reef framework, which may be the habit of this species in life; such habits would account for the slightly deformed shape of these small bivalves and for their apparent rarity. Kay notes that in Hawaii they have been found only in drift, and suggests a nestling habit based on their shape.

Semelangulus sp. cf. crebrimaculatus (Sowerby, 1867)

Three lots of small semelids from Rarotonga resemble the highly variable Semelangulus crebrimaculatus. All 3 are very similar and are at the edge of the range of morphological variability expressed by S. crebrimaculatus elsewhere. They probably represent a distinct species, as they exhibit the following differences from the standard S. crebrimaculatus stock: less pointed umbones, a thinner internal ligament, and stronger external concentric lyrations. Superficially the specimens resemble Tellina semen. They were collected from a reef flat, nestled among rubble (BRAR-71), and from the outer reef slope (BRAR-58, 95). Semelangulus crebrimaculatus s.s. was described from S. Marutea (Tuamotu) and also occurs in Hawaii (Kay, 1979), Fiji, Society and Tuamotu Islands (NMNH and my collections). It is known to me from 14 lots, all from inner reefs at 0.5-20m depths. Kay (1979) notes a depth range of 1-16m in Hawaii.

TRAPEZIIDAE

Solem (1954) revised the family and summarized the available ecological information on its members.

Trapezium oblongum (Linné, 1758)

Trapezium oblongum ranges from Madagascar to Hawaii (Solem, 1954) and to Henderson Island (NMNH). Solem (1954) noted that it "evidently lives in large crevices and underneath coral blocks in reefs and lagoons." I have found live specimens nestled in crevices, under rocks, and exposed on coral rubble.

It is a common species throughout the Cook Islands in most reef habitats. It has been collected on reef flats (BAIU-91, BMAK-13, 17,. 18, 19, 21, 35, 39, 42), in moats (BAIU-51, BRAR-33, 51, 111), in lagoons (BAIU-10, 45, 59, 158), and on outer reef slopes (BAIU-71, 82, 111, 130, 131, 133, 147, BRAR-46, 58, 105, BMAK-22, 24, 31, 44, 68) to a maximum depth of 27-30m. It is similarly common elsewhere in Southeastern Polynesia in similar habitats (NMNH collections).

Trapezium obesum (Reeve, 1843)

At the time of Solem's (1954) review, this species was known only from 4 lots,from the Mauritius, Borneo, and the Ryukyu Islands. Since then it has been recorded from Kenya (Crame, 1986). Here I add the Society Islands and Fiji (my collectionss), Ailuk Atoll (Marshall Is.) (NMNH 615297), and the Cook Islands (G. McCormack, collector) to the species' range.

In the Cooks, Trazium obesum has been recorded only from the Northern Group (habitat unknown). In the Society Islands (5 lots) and in Fiji (3 lots) it is not uncommon in 10-20m deep lagoons. All of the specimens I collected were from sandy bottoms. Although all were dead the habitat in which they were found and the lack of deformities (unlike Trapezium oblongum) indicates an infaunal lifestyle.

VENERIDAE

Venus toreuma Gould, 1850

This species ranges from E Africa to Hawaii (Fischer-Piette, 1975) and to Pitcairn Island (NMNH collections). Oddly it has not yet been found in the Southern Cook Islands, though it is known from Niue and from the Society and Austral Islands. The single Cook Island record comes from a beach on Suwarrow Atoll in the Northern Group, collected by and in the collection of G. McCormack.

Venus toreuma is known abundantly from the outer reef slope of Niue (11 lots, from 8-33m depths) as well as from the barrier reef, lagoon and outer reef slope of the Society Islands. Kay (1979) gives a depth range of 10-500m for the species in Hawaii.

Periglypta reticulata (Linné, 1758)

This species is distributed from E Africa to the Tuamotu Islands (Fischer-Piette, 1975) and Hawaii (Kay, 1979). Kay (1979) noted that it is common in shallow water in

Hawaii. The records at the NMNH and in my own collections indicate a primarily shallow water, inner-reef dwelling species.

In the Cook Islands, the habits of Periglypta reticulata range from shallowly infaunal to crevice-dwelling. Live specimens were encountered in shallow (<2m) water under rocks, generally only partly buried in coarse sand or coral rubble. I have seen one specimen nestled in a barren reef crevice at 3m on the outer reef slope. Records from the Cooks are from reef flats (BAIU-8, 91, BMNG-2, BMAK-19, 21, BRAR-61), outer reef flats (BAIU-24, 25, 29), moats (BAIU-3, 11, 22, 80, 150, BRAR-24, 25, 101, 111, 112, 117), outer lagoons near the outer reef flats (BAIU-7, 56, 59), and outer reef slopes, at 3-20m depths (BAIU-131, BMAK-20, BRAR-16, 21, 105). Periglypta reticulata is very common in shallow inner reef environments, much more so than the collection records indicate. It is rare, however, on the outer reef slope, and the records noted represent all specimens that I have encountered in that habitat. The NMNH holds 2 lots from the outer reef slope, from 14m on Raivavae (Austral Is.) (732190) and from 9-18m on Fatu Hiva (Marquesas Is., 732636). The rest of the over 70 records of the species from Polynesia are all from <3m depths in inner reefs.

Periglypta ?crispata (Deshayes, 1854)

Periglypta crispata refers to different species in different publications, and here I follow Reeve's usage of the name. The identity of this species, as well as that of Periglypta fischeri (Reeve) and of Periglypta chemnitzi (Hanley) (the 3 of which have been involved in various synonymies), needs to be established before the present species can be correctly named. Fischer-Piette (1975) has synomynized P. crispata as well as many other species incorrectly under Periglypta puerpera (Linné).

The range of the species here discussed includes Mauritius, Marshall, Society, Tuamotu, and Gambier Islands (all based on NMNH collections), Fiji (my collections), and the Cook Islands (coll. G. McCormack).

The sole record of the species in the Cooks is from Manihiki in the Northern Group. All records of the species are from islands with well-developed, deep, barrier reef or atoll lagoons. There are 7 lots of specimens from Polynesia that are not from drift; all of these are from lagoons at 2-18m depths. Thus the absence of the species from the Southern Cook Islands may be real and due to the meager development of lagoons there. As the species is found in the Gambier Islands, a latitudinal restriction seems unlikely.

Lioconcha ornata (Dillwyn, 1817)

The genus Lioconcha is in much need of revision. This species ranges from Mauritius and the Gulf of Suez to the Society Islands (NMNH collections). Within the Cook Islands it is known only from Aitutaki (my collections) and Puka Puka (G. McCormack's collections).

In Aitutaki, Lioconcha ornata is strictly an inner reef species, known from the moat (BAIU-3, 11, 22) and especially the lagoon (BAIU-7, 43A, 109, 114, 118, 120, 121, 124, 157) where it is commonly found alive buried in the sand. In the Cook Islands I have never found it on the outer reef slope. In the Society Islands it has similar habits, found commonly in lagoons at 3-16m depths. On Niue, a sparse population of this species occurs on the outer reef slope on a sandy/rubbly reef terrace at 21-33m (my collections). Similarly, off several islands in the Marquesas, 4 lots of this species were dredged in 40-72m depths.

Pitar prora (Conrad, 1837)

Pitar like Lioconcha is in much need of revision. Pitar prora, however, is a fairly obvious species; it is very similar to Pitar obliquata (Hanley), but the latter does not occur in Southeastern Polynesia. All NMNH specimens of P. prora are from Pacific Islands, ranging from the Mariana and Marshall Islands to the Tuamotu and Gambier Islands.

Pitar prora appears to be a strictly inner reef species, known only from moats and lagoons. Accordingly among the Southern Cook Islands it is known only from Rarotonga and Aitutaki. It has been collected in moats (BAIU-3, 11, 22, BRAR-112) and in lagoons (BAIU-43A, 454, 109) but is nowhere abundant. NMNH records of the species in Southeastern Polynesia are from a variety of islands, all with well-developed barrier-reef or atoll lagoons, in the Austral, Society, Tuamotu, and Gambier Isands. All of these records (21 lots) are from moats or lagoons (or their shores), from depths up to 23-25m (NMNH 629987: Fauni Bay, Bora Bora, Society Is.).

Gafrarium pectinatum (Linné, 1758)

This is a variable species ranging from E Africa to the Tuamotu and Gambier Islands (NMNH collections). In the Centyral Pacific it appears to be strictly an inhabitant of inner reefs, preferring shallow, muddy environments such as shallow bays.

In the Cook Islands Gafrarium pectinatum known from Rarotonga, Aitutaki, Palmerston, Puka Puka, Manihiki, Rakahanga and Penhryn, probably existing on all other islands with well-developed reefs as well but being conspicuously absent from the makatea islands. It is abundant and ubiquitous on moats (BAIU-3, 4, 11, 22, 51, 80, BRAR-24, 33, 111, 112) and lagoons (BAIU-7, 43A, 45, 56, 59, 109, 120, 135, 157, 158), and occasionally occurs on reef flat beaches (BAIU-91 and 2 lots in the NMNH). It is extremely abundant in certain shallow bays, e.g. on the muddy sand flats that surround the main island of Aitutaki along its SW, S, E and especially NE sides. The extensive collections of this species from Southeastern Polynesia in the NMNH (over 75 lots) are all from inner reefs, from depths ≤5m. I have, however, on 3 occasions collected dead shells from 10-18m depths in Paopao Bay on Moorea.

GASTROCHAENIDAE

Gastrochaenid sp.

The only gastrochaenids I have seen from the Cook Islands are specimens from Manihiki (in the collection of G. McCormack) which I have not identified. McCann (1974) reports Rocellaria cuneiformis Spengler, 1793 from Manihiki. I seldom searched rocks for endolithic bivalves and they may well occur on the islands I studied.

PHOLADIDAE

Martesia ?striata (Linné, 1758)

A single broken valve of what appears to be this cosmopolitan wood-borer was collected in drift on Mauke (BMAK-18).

CONCLUSIONS

Thirty-four species of heterodont bivalves are recorded here from the Southern Cook Islands (table 1) and 27 are recorded from the Northern Cook Islands (table 2), yielding a total diversity of 39 species for the entire group. A biogeographical analysis of the 12 species that are known at present from the Southern and not the Northern Group would be inappropriate, as the latter has been poorly sampled. Among the 5 species that are known only from the Northern Cooks, 2, Fragum mundum and the gastrochaenid species, may have been simply overlooked in the south because they are small and have cryptic habits. Two others, Trapezium obesum and Periglypta crispata, are known only from deep lagoons and thus their absence from the Southern Cooks may be real, reflecting a lack of suitable habitats. The absence of the fifth species, Venus toreuma, is more difficult to explain because it lives in a variety of reef environments.

Within the Southern Cooks there is a marked decrease in bivalve diversity from Aitutaki to Rarotonga to Mauke, probably in part reflecting a decrease in the size and complexity of the reef systems, especially of inner reef habitats. A lagoon is present only on Aitutaki among the islands of the Southern Group, and 4 of the 5 species known only from Aitutaki in the Southern group are also known only from lagoon and moat habitats. The fifth species, Lonoa hawaiiensis, is known in the Cook Islands from a single specimen.

The Cook Islands' heterodont bivalve fauna does not appear to contain any endemic elements, and no species reach their eastern distributional limit in the Cooks. All of the species encountered are also found in the Society Islands, with the unlikely exception of Tridacna squamosa which at present is known further E only from Ducie. This trend contrasts greatly with that exhibited by scleractinian corals, which are much more diverse in the Cook Islands than in the Society Islands (Paulay, 1985).

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TABLE 1: HETERODONT BIVALVES OF THE SOUTHERN COOK ISLANDS

+ = recorded from island; - = not recorded from island

CHAMIDAE	Aitutaki	Rarotonga	Mauke	Mitiaro	Atiu	Mangaia	Manuae
Chama limbula	+	+	+	-	+	+	+
C. pacifica	+	-	-	-	-	-	-
C. asperella	+	+	+	-	+	+	-
C. "spinosa"	+	+	+	-	-	+	+
C. sp. 2	+	+	+	+	-	-	-
LUCINIDAE							
Codakia punctata	+	+	-	-	-	-	+
C. tigerina	-	+	-	-	-	+	-
C. bella	+	+	+	-	-	+	+
Anodontia edentula	+	+	+	-	-	-	-
CARDIIDAE							
Trachycardium orbitum	+	+	+	-	-	-	-
Fragum fragum	+	+	-	-	-	+	+
Corculum dionaeum	+	-	+	-	-	+	-
TRIDACNIDAE							
Tridacna maxima	+	+	+	-	-	+	-
T. squamosa	+	+	+	-	-	-	-
TELLINIDAE							
Tellina virgata	+	-	-	-	-	-	-
T. crucigera	+	+	-	-	-	-	+
T. palatam	+	+	-	-	-	+	-
T. scobinata	+	+	+	-	-	+	-
T. robusta	+	+	-	-	-	-	-
T. semen	+	+	+	-	-	-	-
Jactellina obliquaria	+	+	-	-	-	-	-
Loxoglypta rhomboides	+	+	+	-	-	+	-
Macoma dispar	+	-	-	-	-	-	-
PSAMMOBIIDAE							
Asaphis violascens	+	+	+	-	-	+	+
SEMELIDAE							
Semele australis	+	+	+	+	-	-	+
Abra seurati	+	+	-	-	-	-	-
Lonoa hawaiiensis	+	-	-	-	-	-	-
Semelangulus sp.	-	+	-	-	-	-	-
TRAPEZIIDAE							
Trapezium oblongum	+	+	+	+	-	+	+
VENERIDAE							
Periglypta reticulata	+	+	+	-	-	+	+
Lioconcha ornata	+	-	-	-	-	-	-
Pitar prora	+	+	-	-	-	-	-
Gafrarium pectinatum	+	+	-	-	-	-	-
PHOLADIDAE							
Martesia ?striata	-	-	+	-	-	-	-

TABLE 2: HETERODONT BIVALVES OF THE NORTHERN COOK ISLANDS

1= NMNH collections; 2 = G. McCormack collections; * = not recorded from Southern Cooks

CHAMIDAE	Palmerston	Suwarrow	Nassau	Pukapuka	Manihiki	Rakahanga	Penhryn
Chama limbula	1	1	-	-	-	-	-
C. pacifica	-	-	-	-	1	-	-
C. asperella	1	-	-	-	1	1	-
C. "spinosa"	-	1	-	-	-	-	-
LUCINIDAE							
Codakia punctata	1	-	-	-	-	-	-
C. tigerina	-	2	-	-	-	-	-
C. bella	1,2	1,2	2	-	2	2	-
Anodontia edentula	1	-	-	-	2	-	-
CARDIIDAE							
Trachycardium ?orbitum	-	2	-	-	-	-	-
Fragum fragum	1,2	2	-	-	1,2	1,2	2
*F. mundum	-	1	-	-	-	-	-
TRIDACNIDAE							
Tridacna maxima	2	2	-	-	2	-	-
TELLINIDAE							
Tellina crucigera	1	-	-	-	-	-	-
T. palatam	1	-	-	2	1,2	-	-
T. scobinata	1,2	2	-	-	-	2	-
Jactellina obliquaria	1	-	-	-	-	-	-
Macoma dispar	-	-	-	-	-	2	-
PSAMMOBIIDAE							
Asaphis violascens	1,2	1	-	1	2	-	-
SEMELIDAE							
Semele australis	1	-	2	-	-	-	-
TRAPEZIIDAE							
Trapezium oblongum	1	1,2	2	1	-	1,2	-
*Trapezium obesum							
VENERIDAE							
*Venus toreuma	-	2	-	-	-	-	-
Periglypta reticulata	1	-	-	-	-	2	-
*Periglypta crispata	-	-	-	-	2	-	-
Lioconcha cf. ornata	-	-	-	2	-	-	-
Gafrarium pectinatum	1	-	-	2	2	2	2
GASTROCHAENIDAE							
*Gastrochaenid sp.	-	-	-	-	2	-	-

TABLE 3: HABITAT SPECIFICITY OF COOK ISLANDS' HETERODONT BIVALVES

For this table, moats and lagoons were separated artificially by a 3m boundary.
++ = common; + = rare; - = absent.

CHAMIDAE	Outer reef slope	Reef flat	Moat	Lagoon
Chama limbula	+	++	++	++
C. pacifica	-	-	+	++
C. asperella	++	++	++	++
C. "spinosa"	?	++	+	-
C. sp. 2	++	?	-	+
LUCINIDAE				
Codakia punctata	+	-	++	++
C. tigerina	+	-	++	++
C. bella	++	++	++	++
Anodontia edentula	++	-	++	++
CARDIIDAE				
Trachycardium orbitum	++	-	-?	++ (deep)
Fragum fragum	-	+	++	++
F. mundum	-	++	++	-
Corculum dionaeum	-	++	++	-
TRIDACNIDAE				
Tridacna maxima	++	++	++	++
T. squamosa	++	-	-	?
TELLINIDAE				
Tellina virgata	-	-	++	++
T. crucigera	++	-	++	++
T. palatam	-	+	++	++ (shallow)
T. scobinata	++	++	++	++
T. robusta	-	-	++	++
T. semen	++	-	++	++
Jactellina obliquaria	++	++	++	++
Loxoglypta rhomboides	++	-	++	++
Macoma dispar	-	-	+	++
PSAMMOBIIDAE				
Asaphis violascens	-	++	++	-
SEMELIDAE				
Semele australis	++	++	++	++
Abra seurati	++	-	++	++
Lonoa hawaiiensis	++	-	-	-
Semelangulus sp.	+	+	?	?
TRAPEZIIDAE				
Trapezium oblongum	++	++	++	++
Trapezium obesum	-	-	-	++
VENERIDAE				
Venus toreuma	++	-	++	++
Periglypta reticulata	+	++	++	-
P. crispata	-	-	-	++
Lioconcha ornata	+	-	++	++
Pitar prora	-	-	++	++
Gafrarium pectinatum	-	+	++	++

APPENDIX: Collection data for specimens cited.

Specimens are from the following islands: BAIU = Aitutaki; BMAK = Mauke; BRAR = Rarotonga; BATI = Atiu; BMNG = Mangaia. All specimens were collected by me, except on Aitutaki: collections also by B. Holthuis and on Mauke: collections also by K. and G. McCormack

BAIU-3: Beach Rapae & N, main I
BAIU-4: Loc.208-209, moat off Rapae, 0.5-1.5m
BAIU-7: Loc. 211, Tapuaetai Motu beach
BAIU-8: E beach, main island
BAIU-9: Loc. 210, S lagoon, 0.5m, on patch reef, live
BAIU-10: Loc. 210, S lagoon, 0-4m, dead
BAIU-11: Loc. 248, Ureia beach
BAIU-12: Loc. 249, moat at Ureia, live in sand
BAIU-22: N Ureia beach
BAIU-24: Loc. 251, outer reef flat, Ureia, 0.5m, dead
BAIU-25: Loc. 251, outer reef flat, Ureia, 0.5m, live, under rock on sand
BAIU-26: Loc. 251, outer reef flat, Ureia, live, attached to underside of rock
BAIU-27: Loc. 251, outer reef flat, Ureia, live, exposed
BAIU-29: N Ureia, outer reef flat, dead
BAIU-36: N Ureia, moat, live in sand
BAIU-39: Loc. 253, near beach on reef flat, N Ureia, dead
BAIU-41: Loc. 255, W outer reef slope, 21-24m, dead
BAIU-43A: Loc. 256, beach and muddy bay, dead
BAIU-44A: Loc. 257, inner moat NW main I, 0.5-1m, dead
BAIU-45: Loc. 260, SW main lagoon, 1-2.5m, dead
BAIU-46: Loc. 260, SW main lagoon, live, in muddy sand
BAIU-50: Loc. 259, SW shore, main island, 5cm, on mud, near shore, live
BAIU-51: Loc. 261, W/NW outer moat, 0.5-1m
BAIU-55: Loc. 262, outer lagoon at mid S reef, 1.5m, live, buried in sand
BAIU-56: Loc. 262, outer lagoon at mid S reef, live, in sand under rock
BAIU-59: Loc. 262, outer lagoon at mid S reef, 0.5-1.5m, dead
BAIU-71: Loc. 264, NW outer reef slope, 24-27m, dead
BAIU-74: Loc. 268, W/SW outer reef slope, 15-18m, dead
BAIU-79: Loc. 269, E outer reef slope, 12-19m, dead
BAIU-80: N beach
BAIU-82: Loc. 268, SW/W outer reef slope, 24-30m, dead
BAIU-91: Loc. 271, Akaiami motu, seaside beach
BAIU-93: Loc. 273, SW/W outer reef slope, 33-36m, dead
BAIU-106: Loc. 271, Akaiami motu, outer reef flat, dead
BAIU-109: Beach & lagoon dredgings at Tautu wharf
BAIU-111: Loc. 274, NW/W outer reef slope, 20-23 m, dead
BAIU-114: Loc. 271, lagoon adjacent to Akaiami motu, 1-3m, dead
BAIU-118: Loc. 277, mid lagoon, 5-6m, live in sand
BAIU-120: Loc. 277, mid lagoon, 5-6m, dead
BAIU-121: Loc. 278, mid lagoon, 5-6m, live, in sand
BAIU-124: Loc. 275, mid lagoon, 4-6m, live, in sand
BAIU-125: Loc. 275, mid lagoon, 4-6m, dead
BAIU-128: Loc. 276, SW lagoon: outer reef flat, dead

BAIU-130: Loc. 280, NE outer reef slope, 12-19m, dead
BAIU-131: Loc. 280, NE outer reef slope, 14-18m, dead
BAIU-133: Loc. 282, N/NW outer reef slope, 19-21 m, dead
BAIU-134: Loc. 279, SW lagoon, 4-7m, live in sand
BAIU-135: Loc. 279, S lagoon, 4-7m, dead
BAIU-147: Loc. 284, N outer reef slope, 26-27m, dead
BAIU-149: Loc. 283, moat NE main I, live underside of rock
BAIU-150: Loc. 283, NE main island moat, 0.5m, live, half buried under rock
BAIU-151: Loc. 277/8, W big lagoon, patch reefs, live, exposed
BAIU-152: NW outer moat, 0.5m, exposed on rubble, live
BAIU-157: Loc. 278, midW big lagoon, 2-5m, dead
BAIU-158: Middle big lagoon, 1-6m, dead

BRAR-2: Loc. 15, Avatiu outer reef slope, 15-25m, dead
BRAR-12: Loc. 19, Avatiu harbor entrance outer reef slope, 9-15m, dead
BRAR-14: Loc. 20, Matavera outer reef slope, 3-7m, dead
BRAR-16: Loc. 20, Matavera outer reef slope, 3m, live, in crevice on reef
BRAR-21: Matavera outer reef slope, 10-20m
BRAR-24: In dredged fine shelly sand from Avatiu harbor
BRAR-25: Arorangi fringing reef, dead
BRAR-27: Loc. 23, Ngatangiia fringing reef, dead
BRAR-28: Loc. 23, Ngatangiia sand flat landward of motu, live, on surface
BRAR-30: Loc. 24, moat at the Rarotongan, 0.2-1m, live in sand
BRAR-31: Loc. 24, moat at the Rarotongan, 0.2-1m, dead
BRAR-33: Arorangi beach
BRAR-40: Loc. 26, reef flat W of Avaavaroa, 0.5m, live in sand
BRAR-42: Loc. 26, reef flat W of Avaavaroa, live underside of rocks
BRAR-43: Loc. 26, reef flat W of Avaavaroa channel, 0.1-0.7m, dead
BRAR-46: Loc. 27, Avarua outer reef slope, 14-17m, dead
BRAR-51: Loc. 30, Titikaveka moat, 0.2-1m, live nestled in dead Lobophyllia head
BRAR-52: Loc. 30, Titikaveka moat, 0.2-1.5m, dead
BRAR-53: Loc. 30, Titikaveka lagoon, 1.5m, live in rubble/sand
BRAR-58: Loc. 32, Avarua outer reef slope, 15-18m, dead
BRAR-59: Loc. 33, N Matavera fringing reef, 0-0.3m, live on undersides of rock
BRAR-61: Loc. 33, N Matavera reef flat, 0-0.3m, dead
BRAR-62: Outer reef slope, 5-25m, live, coll. D. Simms
BRAR-66: Matavera outer reef slope, 15-20m, dead
BRAR-71: Loc. 33, N Matavera fringing reef, nestled among rubble, live
BRAR-74: Tupapa outer reef slope, 10-20m, dead
BRAR-77: Loc. 42, Nikao fringing reef, attached to rock, live
BRAR-80: Arorangi beach
BRAR-86: Near Avaavaroa passage, on fringing reef, dead
BRAR-88: N Matavera reef flat, live, underside of rock, intertidal
BRAR-89: N Matavera reef flat, live, attached to rock, intertidal
BRAR-90: N Matavera fringing reef, nestled among rubble, live
BRAR-93: In Rutaki passage, 12-18m, dead
BRAR-94: Ngatangiia sand flats, dead
BRAR-95: Avarua outer reef slope, 8-13m, dead
BRAR-96: Avarua outer reef slope, 11m, live, hidden in dead coral
BRAR-101: Nikao, mid fringing reef, on rubble under rock, live

BRAR-105: Loc. 156, Avarua outer reef slope, 12-15m, dead
BRAR-111: Nikao beach
BRAR-112: Loc. 213, reef &beach at Motu Toa, dead
BRAR-114: Loc. 214, Nikao, moat, dead
BRAR-115: Loc. 214, Nikao moat, live underside of rock
BRAR-116: Loc.215, Tupapa moat, live attached underside of rock
BRAR-117: Loc. 214, Nikao moat, half-buried in sand, live
BRAR-118: Outer reef slope, live, coll. D. Simms
BRAR-119: Outer reef slope, dead

BMAK-9: Loc. 65, S Taunganui Landing, outer reef slope, 12-22m, dead
BMAK-11: E beaches
BMAK-12: Misc. beaches
BMAK-13: N beaches
BMAK-16: Loc. 91, near Anaio, moat, buried in sand/rubble
BMAK-17: E & SE beaches
BMAK-18: E beaches
BMAK-19: E to SW beaches
BMAK-20: Loc. 94, Kimiangatau outer reef slope, 20-24m, dead in rubble channel
BMAK-21: E to SE beaches
BMAK-22: Loc. 86, Taunganui outer reef slope, 14-18m, live under rocks
BMAK-23: Loc. 95, Kimiangatau outer reef slope, 18-24m, dead
BMAK-24: Loc. 84, Tukume Landing outer reef slope, 18-21m, dead
BMAK-27: Misc. beaches
BMAK-28: Loc. 94, Kimiangatau outer reef slope, 18-24m, live on underside of rock
BMAK-29: Loc. 66-67, nr. Taunganui Landing, outer reef slope, 14-24m, dead
BMAK-31: Taunganui Landing outer reef slope, 15-18m, dead in sand/rubble channel
BMAK-32: Nr. Taunganui Landing, 12-20m, dead on sand
BMAK-34: Taunganui outer reef slope, 18-24m, dead on/in sand
BMAK-35: NE beaches
BMAK-36: Loc. 86, Taunganui Landing outer reef slope, 14-18m, dead
BMAK-38: Near Taunganui outer reef slope, 20-25m, dead in sand
BMAK-39: E beaches
BMAK-40: Near Anaputa, outer reef slope, 3-7m, live
BMAK-41: Loc. 66, nr. Taunganui Landing, outer reef slope, 14-18m, dead
BMAK-42: E beaches
BMAK-43: Loc. 70, nr. Taunganui Landing, outer reef slope, 12-18m, dead
BMAK-44: Loc. 64, Nr. Taunganui Landing outer reef slope, 6-15m, dead
BMAK-68: Loc. 84, outer reef slope, 18-21m, live, exposed on coral rubble
BMAK-69: Near Taunganui landing, outer reef slope, 18-21m, live in sand
BMAK-70: Loc. 93, Uriaata Landing, reef flat, buried live in sand
BMAK-71: Loc. 78, Kimiangatau, outer reef slope, 50-52m, dead
BMAK-73: Loc. 85, Anaio Landing, outer reef slope, 24-27m, dead
BMAK-74: Loc. 83, outer reef slope off Po'oki Landing, 6m, live, attached to bare reef

BATI-1: Reef flat SE of Tanganui landing, dead
BATI-3: Outer reef slope, 2-12m, live, attached to Leptoria

BMNG-2: Beach nr. Oneroa landing

BMNG-4: Ivirua beach
BMNG-5: Reef flat at & N of Oneroa, live
BMNG-6: Reef flat at & N of Oneroa, dead

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ATOLL RESEARCH BULLETIN

NO. 299

THE SEAWARD MARGIN OF MAKATEA, AN UPLIFTED CARBONATE ISLAND (TUAMOTUS, CENTRAL PACIFIC)

BY

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RESUME

Après une brève présentation de l'histoire géologique du nord-ouest de l'archipel des Tuamotu, présentation qui prête une attention toute particulière à l'île de Makatea, un pseudo-atoll *sensu* AGASSIZ, l'article décrit les grands traits géomorphologiques et bio-écologiques de la bordure récifale actuelle de cette île.

L'île de Makatea (7 km x 4.5 km) présente une géomorphologie récifale très particulière dont les caractéristiques résultent d'évènements liés à la tectonique globale ou régionale (eustatisme, climat, soulèvement...) survenus principalement durant le quaternaire, les facteurs écologiques intervenant ici de manière particulièrement modérée.

On distingue trois types de formations, en fonction du degré d'évolution et d'exposition: sur les côtes nord et est de l'île, des récifs tabliers assimilables à des trottoirs d'algues calcaires - sur la côte occidentale (baie de Moumu), des récifs frangeants de mode calme - sur les côtes sud-ouest et sud-est, des récifs frangeants de mode battu.

Les caractéristiques écologiques principales de la bordure récifale actuelle sont la monotonie et la pauvreté de la faune benthique, d'une part, et, d'autre part, l'importance des algues brunes (notamment *Turbinaria*).

La flore algale (45 espèces) est constituée d'un mélange d'espèces typiques d'îles hautes volcaniques (Phéophycées) et d'espèces typiques d'îles basses carbonatées (Chlorophycées).

Alors que les colonies de Madrépores vivant sur les platiers et les fronts récifaux sont peu développées (encroûtantes) et peu abondantes, une majorité des pentes externes est caractérisée par la richesse et la vitalité des communautés coralliennes où les formes dominantes appartiennent aux genres *Acropora*, *Porites*, *Pocillopora* et *Astreopora*.

La macrofaune benthique associée (Mollusques, Echinodermes...) est plus pauvre que celle généralement observée le long des récifs extérieurs d'atolls polynésiens; les Mollusques apparaissant particulièrement sous-représentés. Ce fait est probablement dû à la réduction des biotopes réprésentés sur Makatea, et à l'émersion prolongée de nombre de platiers récifaux.

Makatea semble être une île très particulière dans l'ensemble de l'archipel des Tuamotu; aussi, les principaux traits écobiologiques soulignés ici ne peuvent être utilisés comme modèle pour les îles polynésiennes avoisinnantes. En revanche, c'est un champ d'expérimentation très intéressant d'un point de vue géologique, car l'île recèle près de 25 millions d'années d'histoire du Pacifique, à notre portée à la surface de l'océan. De futures recherches sur Makatea devraient se focaliser de préférence sur les dépôts carbonatés Miocène: nature et distribution des principaux constructeurs, croissance récifale et modifications en liaison avec la tectonique globale, premières phases des processus de diagénèse et phosphatogénèse.

THE SEAWARD MARGIN OF MAKATEA, AN UPLIFTED CARBONATE ISLAND (TUAMOTUS, CENTRAL PACIFIC)

BY

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INTRODUCTION

Located at 148°15' West and 15°50' South, in the northwesternmost part of the Tuamotu archipelago (Central Pacific), Makatea island is isolated from its nearest neighbouring atolls, Rangiroa and Tikehau by about 80 km, and it is 245 km from its closest volcanic neighbour, Tahiti. This island rises at least 3,500 m above the sea floor (Figure 1).

Like all Tuamotu islands, Makatea consists of biogenic deposits. But unlike the other islands which rise no more than a few metres above sea level and surround lagoons, Makatea reaches more than 100 m in elevation. Based on foraminiferal assemblages, age determination clearly indicated that the island frame was built up during Early Miocene (Montaggioni *et al.* 1985 a; Montaggioni, 1985).

Makatea, measuring 7 km by 4.5 km, is a crescent - shaped island, irregular in outline (Figure 2). Its northwestern and northeastern faces are more or less concave, respectively occupied by the bays of Temao and Moumu. Makatea is partly surrounded by a reef margin extending outward some 100 metres from the base of the cliffs and ending in subvertical drop-offs.

After presenting the geological history of the northwestern Tuamotu islands with special reference to Makatea as an atoll-like island, the present contribution describes the main morphological, sedimentological and ecological features of the seaward reef margin of this island.

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MAKATEA, A HIGH ATOLL-SHAPED ISLAND FROM THE NORTHWESTERN TUAMOTU RIDGE.

A. GEOLOGICAL HISTORY OF THE NORTHWESTERN TUAMOTUS

According to bathymetric maps (Monti 1974 ; Mammerickx *et al.* 1975)., the northwestern Tuamotu atolls cap the tops of volcanic cones which rise steeply not from the ocean floor, which is 4,000 to 4,500 m deep in this region, but from a huge ridge forming wide shelves ranging in depth from 1,500 to 3,000 m. Summarizing Deep Sea Drilling Project (DSDP) results, Clague (1981), Schlanger (1981) and Schlanger *et al.* (1984) noted that for the Line and northwestern Tuamotu chains, the foundations of extinct volcanoes appear to have been simultaneously, and not sequentially, active. As a result, these results are reviving Menard (1964)'s postulated Darwin Rise, which he envisaged as having gradually foundered after the end of volcanic activity, leaving subsidence reefs in its wake. Geomorphological and geochronological evidence indicates that the formation of the Tuamotu chain is much older than that of the surrounding other French Polynesian islands. The existence of a massive submerged ridge and lack of high volcanic islands are in accordance with average ages deduced from DSPD. At sites 76 (Hays *et al.* 1972) and 318 (Schlanger *et al.* 1976) drilled on the northwestern flank of the Tuamotu ridge, and on the ridge itself, reefal debris of Early to Late Eocene age were sampled. It appears that the Tuamotu reefs have contributed to deep-water sedimentation since Early Eocene (50-51 m.y.). These fossils can be interpreted as indicative of a possible date for cessation of volcanism in the Late Cretaceous to Early Eocene for at least the northwestern part of the Tuamotu chain (Schlanger 1981).

The Tuamotu islands are relatively close to the East Pacific Rise where lithospheric cooling induces most rapid deepening (Heezen *et al.* 1973). Likewise the large number and close spacing of the Tuamotu atolls is indicative of their origin in shallower waters close to the East Pacific Rise; according to Scott and Rotondo (1983), on average more of the newly formed seamounts would have kept pace with sea level here, simply because of the shallower water. Although Farrar and Dixon (1981) think that the Tuamotu volcanic basement is the product of a mechanism consistent with the fixed hot spot hypothesis, the early history of such a bathymetrically complex chain might not have followed a simple pattern. One of the major objectives of drilling in the Line-Northwestern Tuamotu lineation during DSDP Leg 33 was to determine if the volcanism responsible to the building of this chain was age progressive and thereby compatible with a hot spot origin. The results from drilling may be summarized as follows (Clague 1981) : 1) the age data obtained do not allow for an unambiguous test of the hot spot model for the origin of the Line-Northwesternmost Tuamotus. It is possible that the whole chain formed almost simultaneously between 80-85 m.y.B.P.; 2) the carbonate cores of the atolls are probably coeval along the chain ; 3) the chain is older than the oldest seamounts in the Society Islands. Jackson and Schlanger (1976) suggested that the entire ridge underwent epeirogenic uplift 80-85 m.y. ago which moved the preexisting shield volcanoes into shallow water; the Line and Northwestern Tuamotu islands beginned to be capped by reefs about 70-80 m.y. B.P. during subsidence following the epeirogenic pulse. Thus the major volcanic relief of the northwesternmost portion of the Tuamotus may be constructed during a period of widespread volcanic activity which affected the central Pacific region; this period of volcanism may be related to some other type of midplate mechanisms rather than hot spot activity or even to an activity related to old oceanic spreading centres.

A number of atolls are elevated in the northwestern Tuamotu region, all located in the vicinity of recently active volcanoes (Tahiti, Moorea, Mehetia) (Figure 3). As

topographic profiles across similar oceanic volcanoes reveal moats and arches in the surrounding bathymetry, Mc Nutt and Menard (1978), Lambeck (1981) argued that the tectonic uplift of these atolls has resulted from the loading effects of the nearby Tahiti volcanic complex. A crustal moat developed peripheral to Tahiti, Moorea and Mehetia volcanoes; beyond the outer edge of the moat, flexuring developed an arch which experienced uplift in the order of tens of metres. Islands situated at various distances from this new loading mass can isostatically respond differentially: those within the developing arch are slowly elevated. It appears that the emerged atolls have been uplifted, with respect to present day sea level, by 3-6 m with the notable exception of Makatea (highest point : 113 m); the latter is also the island closest to the centre of the load and the one which would be expected to be uplifted most (Table 1). The ability to explain the variations in elevations of the arrays of similar atolls is a powerful test of Mc Nutt and Menard's theory. This explanation seems to be far more satisfactory than any hypothesis of a global change in sea level (Veeh 1966) or a regional elevation induced by overriding an asthenospheric bumps (Menard 1973). However, Jarrard and Turner (1979), Lambeck (1981) and Montaggioni (1985), while agreeing with this conclusion, disagree as to the exact amount of resultant elevational displacement. As Moorea, the oldest shield volcano, is dated of about 1.5 m.y. (Duncan and Mc Dougall 1976), the uplift is thought to have initiated during Early Pleistocene (Montaggioni, 1985; Pirazzoli and Montaggioni, 1985) rather than in Miocene times (Doumenge 1963, Chevalier 1973). Irrespective of the duration of vertical deformation of the underlying lithosphere , isostatic equilibrium still has not been reached in this area (Pirazzoli and Montaggioni, 1985).

Finally, Scott and Rotondo (1983) think that, since the larger Tuamotu atolls are in an ideal position south of the equator, many of them will survive for many million years during their slow passage through warm equatorial waters. But, they emphasized, however, that some smaller atolls will not survive even in equatorial waters because island pedestals sink into deeper water the living reef tops will become so narrow that they will no longer support any island form whatsoever.

Table 1 : Observational evidence for uplift of atolls associated with the Tahiti - Moorea volcanic load (modified from Mc Nutt and Menard, 1978 and Lambeck, 1981).

ATOLL	distance from Tahiti (km)	observed uplift (m)	theoretical uplift (m)	Misfit
Makatea	245	113	71.9	- 41.1
Mataiva	325	3.5	3.1	- 0.4
Rangiroa	340	3.5	0.0	- 3.5
Tikehau	345	4.0	0.5	- 3.5
Niau	350	5.0	6.5	+ 1.5
Kaukura	370	3.5	3.0	- 0.5
Anaa	430	6.0	5.3	- 0.7

B. MAKATEA AND THE ATOLL CONCEPT : TO BE OR NOT TO BE AN ATOLL ?

Darwin's deductive model of atoll genesis (1842) postulated that, as a subsiding volcanic island base disappeared below sea level, an atoll formed. Most atolls usually sink, as the sea floor cools and, consequently, sinks. However, tectonic displacements or eustatic changes preclude subsidence and atolls occasionally are elevated or emerge. Thus, numerous aspects of atoll history remain controversial, particulary the origin of the typical gross morphology showing a submergent ring around a broad, flattish lagoon. Earlier investigators (Forbes, 1893 ; Agassiz, 1903) then Hass (1962) and Menard (1964) suggested that such ring and lagoon were formed in many ways.

Arguments were advanced supporting the theory that such usual features resulted primarily from carbonate solution (Asano, 1942 ; Mc Neil, 1954 ; Purdy, 1974 ; Bourrouilh-Le Jan, 1977).

High coral islands all display a lot of similar characters : saucer-shaped gross morphology ; high peripheral rim with scattered residual hills ; pinnacled and deeply pitted surfaces ; single or multiple central depressions with isolated karstic towers ; outer and inner cliff walls.

However, long-term and presumably intensive solution alteration occurred in some places and not in others. Menard (1982) argued that one of the most important regional variables is the amount of rainfall. He demonstrated that the depth of atoll lagoons is largely a function of rainfall ; the depth generally increases with rainfall. Persistence of a number of Pacific elevated coral islands for millions of years can be ascribed to very low average annual rainfall (in cm per/year) : Makatea, 168 ; Ocean, 185 ; Mangaia, 191 ; Niue, 195 ; Nauru, 206. Two global factors which may be significant in terms of atoll morphology, are evaporation and climatic changes through time. The highly uplifted islands mentioned above are only in regions where evaporation exceeds rainfall. Moreover, regional variation in lagoon depth can result from a shift towards aridity during glacial periods. Consequently, elevated coral islands may be eroded very slowly in areas of low rainfall.

In brief, when tectonic or eustatic effects changed originally low reef islands into high islands, they were altered to a depth depended upon the amount of rainfall or the balance between rainfall and evaporation (Menard, 1982). The dominance of solution caused the top of the islands to be saucer-shaped. As sea level rose, the subaerially eroded surfaces may be progressively both colonized outward by builders or filled inward with unconsolidated skeletal sediments. As Bourrouilh-Le Jan (1977) and Scott and Rotondo (1983) concluded, the atoll concept must be mainly related to the recent eustatic and tectonic history of oceans. If, according to many authors, the term atoll refers to a Darwinian history of unceasing subsidence, Makatea and similar carbonate islands are not true atolls, but rather pseudo-atolls in the sense of Agassiz (1903 p. 105), i.e. ring-shaped reefs not formed by subsidence.

THE SEAWARD MARGIN : MEAN FEATURES

The survey of submarine features was limited to a few sites regarded as typical of the island, on the basis of mainland structure and exposure to wave action. The seaward reef margin of Makatea can be subdivided into three zones which are caused by differences in Recent morphologic evolution : an emerged, narrow reef flat zone of Late Holocene age (Montaggioni *et al.* , 1985 b), a shallower forereef zone whose lower limit is that of coral and calcareous green algal growth (about 60 m deep), and a deeper forereef zone which forms the upper parts of the island slope.

A. THE REEF FLAT ZONE

1. Morphology

Three fringing reef types can be distinguished on the basis of degree of evolution and exposition : apron reefs, high - energy and low energy reefs.

- Apron reef flats

At the base of the cliffs, at the extreme northern end and along the eastern coast of the island, living organic buildups occur as very narrow (3-10 m) pavements (Figure 4). The reef flat consists of a subhorizontal smooth-surfaced flagstone mainly made up by coralline algae (Figure 5).

- High energy fringing reef flats

Ranging in width from 70 to 90 m, these reefs are situated along the southwestern to southeastern shores. From sea landward two morphologic units have been described : outer reef front, reef flat.

The reef front is identified with the uppermost parts of outer organic spurs which emerge 0.40-0.50 m at low tide. Better coralline algal rims develop in higher wave energy. Thus a typical algal ridge is found on the southeastern reefs (Figure 6).

The reef flat resembles a deeply pitted and honeycombed flagstone. Just behind the algal ridge the substratum is furrowed with an outer moat parallel to the reef front , 10-20 m wide and 0.10 m deep. The surface becomes increasingly irregular and uneven : shallow erosional basins occur from place to place. In very exposed areas the reef flat topography is raised with conglomeratic crags, 2-10 m wide, 10-20 m long, oriented perpendicularly to reef front. Reaching 0.50 to 0.80 m above low tide level, these crags alternate with shallow (0.5 - 1 m) and narrow (1-2 m) grooves running across the reef flat zone from reef front shoreward. The crag-groove system tends to disappear towards the southern and southwestern areas, giving place to a common pitted flagstone. Generally the reef flat zone is separated from backreef sandy beaches by a narrow (5-10 m wide) and shallow (about 1 m deep) channel.

- Low-energy fringing reef flats.

Varying in width from 30 to 120 m, these reefs are found along the sheltered western coast and within Moumu Bay. Unlike that of the exposed reef tracts the reef front here is a subplanar platform (so-called *outer glacis*), a few metres in width. It is bounded shoreward by a microcliffed erosional step, 0.20-0.30 m high, spreading over 10 m and gently sloping towards the inner reef flat (Figures 7, 8).

The reef flat zone begins at the upper part of the microcliff; it consists of an organic planar, partly eroded flagstone exhibiting a number of shallow pools practically devoid of skeletal deposits. Behind this zone sand to pebble beaches or beach rock outcrops begin ; they gradually increase in width southward and eastward until they reach some 200 m wide at their widest part.

2. Ecological characteristics of benthic communities

- The outermost parts of the reef flat zone

In high-energy (eastern to southwestern) areas, construction is almost exclusively made by coralline algae (*Porolithon onkodes, P. craspedium*) which locally form a well-developed ridge. It reaches its maximum width (25 m) and thickness (0.15 m) along the southeastern area of the island. At the foot of the cliffs, in poorly developed reef areas, the algae *Porolithon* grow up to 1m high above mean sea level

as vertical, thin veneers. The morphogenetic role of calcareous red algae progressively declines towards the more protected, southern, then southwestern shores. The front zone, therefore, grows richer in soft macroalgae typical of the reef edges of atolls, such as the brown algae *Lobophora variegata* and the green algae *Microdictyon, Neomeris, Halimeda, Caulerpa* and *Avrainvillea* . The coral fauna is very scattered or lacking; however some decimetre sized *Porites, Montastrea* and *Montipora* colonies and the hydrocoral *Millepora* were found. Consequently, except for the echinid *Colobocentrotus pedifer*, and a few crustaceans coming from the forereef zone, the fauna consists principally of molluscs. The dominant species are *Turbo setosus, Patella flexuosa, Drupa ricinus* and *D. morum*. Along the base of the exposed cliffs, *Thais aculeatus* assemblages occur up to 0.50 m above mean sea level ; this is successively replaced, at the height of 1.5 m, by a population of *Nerita plicata,* then, at the height of 2-2.5 m, by a population of *Littorina coccinea* (Figures 9, 10).

In low-energy (western to northeastern) areas, the reef front (so-called outer glacis) is characterized by a relative rich cover of coral communities in comparison with those from high-energy fronts. The dominant species is *Acropora rotumana* forming encrusting colonies. The subordinate forms consist of stunted *Porites sp., Leptastrea purpurea, Montipora sp., Montastrea curta* colonies, associated with scarce Faviidae. On the outer margin and in the outer part of the spurs, the hydrocoral *Millepora platyphylla* occur here and there. The amount of coral coverage ranges from 0 to 40%; it reaches maximum values at the outermost part of the glacis, while the top of the inner microcliffed step is totally devoid of corals. The algal cover fairly develops; coralline algae (*Lithophyllum sp.*) make up a skin-deep veneer only. Floristically speaking, the originality of the glacis lies mainly on the occurrence of an inner brown algal belt (*Lobophora variegata*).

Such an assemblage occurs wherever an erosional stepped reef front exists. In contrast, other Pheophyceae, and particularly *Turbinaria ornata* , are only observed at the vicinity of man-inhabited areas (Temao, Moumu); it is possible that the settlement of this brown alga may be a consequence of some human activity. The molluscan fauna is restricted to a few Muricids (*Drupa ricinus, D. morum, D. clathrata, Thais armigera, T. aculeatus, Mancinella tuberosa*) (Figures 11, 12).

- The inner parts of the reef flat zone

In exposed areas, just behind the algal ridge, the moat which parallels the reef front, is colonized by dense Rhodymenial or, locally, *Neomeris vanbosseae* turfs. Likewise this zone is rich in molluscs (*Thais aculeatus, Drupa ricinus, Tectarius grandinatus, Morula granulata, Bursa bufonia*); but it contains few corals. Directly landward of the outer moat, the reef flat grows richer in macroalgae. The brown alga *Lobophora variegata* becomes the dominating species whereas *Neomeris* is more or less absent. Three *Halimeda* species are present, in association with two other Chlorophyceae (*Caulerpa urvilliana, C. pickeringii*) and the red alga *Liagora ceranoïdes*

In the areas periodically subjected to exposure, the green alga *Cladophoroa* sp. flourishes. Molluscan communities are composed of *Tridacna maxima* (stunted shells), *Bursa bufonia, Thais armigera* and *Cypraea caputserpentis* . Locally, *in situ* dead *Chama iostoma* are found (Figures 9, 10). Corals are very scarce.

The crag-groove system is mainly colonized by molluscs (*Littorina coccinea, Thais aculeatus, Tectarius grandinatus, Morula granulata*). The bottom of pools and grooves are commonly occupied by cyanophytes (*Hassalia byssoïdea*), a few holothurids, crustaceans pagurids and molluscs neritids (*Clithon chlorostoma*). This zone also contains a few corals; colonies are stunted (mean diametre : 0.20 m) and form small clusters in ecologically favourable sites, i.e. along the margins of acting reef flat grooves. The most common forms are *Porites cf. compressa* and *Montastrea curta* ; the

subordinate ones are *Pocillopora verrucosa, Favia stelligera, Leptastrea purpurea, Pavona clavus, P. varians* and *Psammocora contigua.*

In sheltered areas, at the top of the microcliff where the reef flat zone originates, a thin *Lithophyllum* rim occurs. Macrobenthic organisms are restricted to a soft algal turf (*Liagora ceranoïdes, Lobophora variegata*) inhabited by sparse molluscan populations (*Mancinella tuberosa, Thais aculeatus*). Shoreward of the microcliff, reef builders are almost absent.The coral fauna consists only of small-sized *Porites, Acropora* and *Leptastrea* colonies, and scattered calcareous algal crusts. This area consists mainly of an algal belt in which *Lobophora variegata* dominates along with various associated green algae (*Cladophora, Caulerpa, Halimeda*). Within pools, benthic communities are composed of the holothurid *Holothuria atra* and numerous molluscs (*Cypraea moneta, Morula granulata, Mitra litterata, M. pauperculata, Conus lividus*) most of which are carnivorous.

The inner limits of the low-energy reef flat are characterized by the presence of cyanophyte films (*Hassalia byssoïdea,* endolithic *Entophysalis granulosa*) associated with green algal populations (*Cladophora*). The macrofauna includes holothurids (*Holothuria*), grass-eating (*Puperita reticulata*) or carnivorous (*Cypraea moneta, C. depressa, Bursa bufonia, Morula granulata*) gastropods.

At the base of the cliffs and on the neighbouring beach-rock outcrops, irrespective of the areas considered, algal communities composed of *Hassalia* and *Entophysalis* are common. While echinoderms are sparse, molluscs constitue dense populations rich in neritids (*Nerita plicata, Clithon chlorostoma*) and littorinids (*Littorinea coccinea*) (Figure 11).

3. Unconsolidated sedimentary bodies

Modern skeletal sediments are mainly deposited as beaches.There are relatively well-developed along the southwestern and eastern margins of the island.

North of Temao the beach gradually narrows until it finally ends at the base of the cliffs. On the fringing reef flats and along the shallower fore-reef zone, loose skeletal deposits occur as thin and scattered layers and pockets. Figure 13 illustrates the textural and compositional characteristics of some typical sediment deposits.

- Texture

Two textural parameters (mean size Mz, sorting So; according to Folk and Ward, 1957) were graphically determined from the grain-size cumulative frequency curves.

Sediments from Moumu beach (eastern coast) are coarse to very coarse (Mz = 0.67-1.26 mm), well sorted (So= 0.77 - 1.41) sands. Those from Temao beach (western coast) consist chiefly of granules (Mz = 2.27 - 3.09 mm), generally poorly sorted (So = 1.15 - 1.79). Along the most exposed coastal areas the sands from the lower beach zone are very coarse-grained (Mz = 1.19 - 1.82 mm) and very well sorted (So = 0.58 - 0.87). In contrast, sediments trapped in erosional pools breaking the fringing reef surfaces, are of various types : well sorted (So = 0.80 - 0.87), coarse to very coarse sands (Mz = 0.66 - 1.71 mm); poorly sorted (So = 1.72) pebbles (Mz = 5.29 mm), or poorly sorted (So = 1.70) medium sands (Mz = 0.28 mm). Along the outer reef slopes, irrespective of the area considered the deposits consist mainly of very coarse (Mz = 1.23 - 1.31 mm), well sorted (So = 1.04 - 1.20) sands.

- Constituents

The constituent analysis data presented herein was processed in a manner similar to that defined by Gabrié and Montaggioni (1982). The grains counted were catalogued in 9 constituent categories (e.g. corals, coralline algae, *Halimeda* , molluscs, benthic foraminifers, crustaceans, bryozoans, serpulid worms and echinoderms); unidentified

grains were left out from the statistical treatment since they are not quantitatively significant. In addition, the main foraminiferal genera were recognized.

The major sediment contributors are corals and calcareous algae (coralline forms and *Halimeda*). Foraminifers and molluscan elements are present in substantial content, whereas crustaceans, echinoderms, serpulids and bryozans play a minor sedimentogenetic role.

The coral component is the most ubiquitous in the whole reefal deposits; its abundance ranges between 20 to 38% of the total sediment particles. Amounts in coral grains increase rapidly seaward in the fore-reef zone (45-60%) as the cover rate of living corals increases. The abundance of coral material is originally due to the extensive development of forereef communities (herein), whose skeletal production partly supplies the inner reef areas during storm surges. Although coral elements are possibly widespread within all the size classes, they are best represented in coarse to medium-sized populations.

Likewise coralline algal detritus is widespread. It reaches levels of 22-37% on the fringing reef system as well as on the upper fore-reef zone. As could be expected the highest frequency of the coralline algal component is found in the high-energy reef areas where an algal ridge develops. Thus the occurrence of coralline algal grains in sediment can be considered a sensitive index of the close proximity of areas of high coralline algal productivity since their ability to be dispersed has been recognized to be particularly low (Maiklem, 1968. Montaggioni, 1978). This algal component is a significant contributor to sediment, chiefly in the size fractions greater than 1 mm.

Concerning *Halimeda* , the sediment production varies largely from place to place. The highest concentrations develop along the lower beach zones of the western and southwestern faces of the island (36%). In contrast, values are particularly low (4-5 %) along the northeastern margin and the whole shallow fore-reef zone (5-7 %). The distributional patterns of *Halimeda* seem to be controlled by sediment transport patterns rather than by the development and location of the living organisms. Indeed, along the fore-reef zone, *Halimeda* turfs reach rates of coverage up to 30% of the substrate, while they are practically lacking on the reef flat zones (herein). Owing to their great ability of movement, *Halimeda* plates are dispersed, from the outer slope and concentrate preferentially shoreward, i.e. in the more protected areas of the coastal margin. This is in accordance with previous investigations carried out in various reef provinces (Jindrich, 1969; Masse, 1970 ; Maxwell, 1973; Gabrié, 1982). The occurrence of *Halimeda* fragments is reasonably similar in all the size ranges.

Sediments contain relatively low amounts of molluscan particles which are appreciably equal for the whole environments (7-14 %). Higher values are found in Moumu bay (16%). These percentage data are possibly a reflection of the distributional pattern of molluscan populations since they are assumed to be relatively poor (herein). However these results may be also explained in terms of higher rate of dilution by other components as in some indopacific reef areas (Montaggioni, 1978; Gabrié, 1982). Molluscan grains are preferentially restricted to finer fractions.

Amounts of foraminiferal tests vary largely from reef front to beach (3-23%). The highest amounts develop in Moumu bay and the southern coast. Beyond the outer slopes, their abundance declines markedly so that the sediment contains 0.6 to 1.3% foraminifers. The most abundant forms belong to encrusting ones, such as Homotrematidae *(Miniacina alba, M. miniacea, Homotrema rubrum* : 0.2-7% of the total sediment grains ; *Carpenteria* : 0.2-4 %). The subordinate producers are Soritidae *(Sorites* : 0-3%) and Amphisteginidae *(Amphistegina* : 0-4%). The other types are rare : Planorbulinidae *(Planorbulina* = 0-0.5% ; *Gypsina* = 0-0.3%), Miliolidae (0-1%) and Cymbaloporidae (0-1%). The results obtained contrast strongly with the distributional pattern of foraminiferal populations in various indopacific reef areas where foraminifers are one of the major contributors to bioclasts (see, for instance, Cushman *et al.*, 1954;

Le Calvez *in* Guilcher *et al.*, 1965; Lewis, 1969; Masse, 1970; Coulbourn and Resig, 1975; Le Calvez and Salvat, 1980; Montaggioni, 1978, 1981; Venec-Peyré and Salvat, 1981; Gabrié, 1982). These data may be interpreted as indicating a lack of favourable environments for most types of foraminifers. While encrusting forms can easily find available substrates, epiphytic and free benthonic species do not flourish on Makatea reefs, as a consequence of lack of dense sea grass beds and wide subtidal sediment accumulations.

Although they never constitute an important sediment source, crustaceans (0.2-5%), serpulids (0.2-3 %) and echinoderms (0.2-2.9 %) contribute to present-day sedimentation in a wide spectrum of reef zones. These components seem to be closely related to corresponding fauna development and location. Bryozoan debris are uncommon; concentrations never exceed 0.5%. Such a low concentration is probably more function of their low contribution to reef framework than of their low ability to resist diminution by abrasion.

B. THE SHALLOWER FOREREEF ZONE

1. Morphology

Three shallower fore-reef types can be recognized in the fringing reef flat zones of Makatea. Development of physiography patterns appear to be controlled by antecedent topography and degree of water turbulence (Montaggioni *et al.,* 1985 b).

In poorly developed reef areas (apron reefs), the morphologic zonation is as follows, from the reef front seaward (Figure 5): upper drop-off, furrowed platform, zone of coral patches and lower drop-off . Below a depth of 4 m , the intertidal reef pavement changes abruptly into a subvertical (60°) escarpment (so-called upper drop-off) which may grade laterally into a typical spur-and-groove system where the best developed apron reefs occur. Deeper, an upper, markedly furrowed, gently dipping (20°) terrace is found between depths of 4 and 9 m . Then the zone of coral patches extends seaward for some thirty metres; it is a very gently sloping (5°) platform partly covered with skeletal sediments and elongate coral buildups, a few metres in diameter. This platform is bounded outward by a 1 - to - 2 m thick coral rim, having no grooves or distinctive relief feature. The latter is followed with a lower drop-off which exhibits two convex-upward breaks in slope at about 14 and 20 m , leading to a marked change in gradient (45-60°). At depths greater than 20 m, the margin slope has a linear talus of coarse-grained skeletal material, parallel to the reef front; these stable alignments of organism-encrusted, debris alternate with those formed by unconsolidated slumping material. No organism-built buttress is observable here.

Seaward of the high-energy fringing reef flats, the shallower fore-reef zone over 10 m deep has a relatively steep (20-30°) spur-and-groove system. Between 8 and 11 m deep, the slope increase abruptly (50-60°) and changes into a drop-off of low relief (Figure 6).

Seaward of the low-energy fringing reef flats, the spur-and-groove zone extends downward to depths greater than 10 m. Below 6 m deep, the slope is gentle (15-20°) and grooves are narrow (1-1.5 m) and deep (2.5 m). Deeper, the slope becomes steeper (60°-70°), while grooves change into wide channels for basinward transport of fore-reef material, and connect with a smooth-surfaced drop-off (Figure 7).

Locally, all along its edge, the coastal cliff is dissected by vertical extensional fracture networks roughly running perpendicular to the cliffline. These faults belong to the NNW-SSE trending system which dissects the whole island mass into several blocks (Montaggioni, 1985).

Fractures are locally infilled with consolidated, gravity-accumulated material

consisting of pebbly to gravely reef limestone. They can extend seaward through the late Holocene reef tract, suggesting that tectonic extensional movements have occurred very recently. Underwater examination shows that the uppermost part of the forereef zone is morphologically fault-controlled. For example while breaks in slope (lower boundary of the spur-and-groove system) generally occur between depths of 6 and 11 m along the seaward margin of the island, they are found here at 20 m deep. Moreover, the spur-and-groove zone is replaced by a very uneven, steep platform littered with large erratic boulders (Figure 14). All this indicates that the upper part of the outer slope has recently slumped basinward.

2. Ecological characteristics of benthic communities

At the base of the cliffs, in reefless areas as well as in apron reef areas, the upper drop-off which extends to depths of 4 m , is colonized by an upper green-algal belt (*Microdictyon okumuraii, Neomeris vanbosseae, Halimeda taenicola, H. micronesica, Caulerpa urvilliana, C. seurati, Avrainvillea sp.*) and a lower dense population of boring echinids (*Echinometra mathaei).* At depths of 9-10 m , the zone of plurimetre-sized coral patches have a coral coverage ranging from 50 to 80% of the substrate surface, where *Pocillopora* colonies dominate. The coral rim, which marks the outer limit of the zone of patches, is formed by the species *Pocillopora verrucosa, P. eydouxi, Acropora spp., Astreopora myriophthalma, Porites sp.*. their extent of cover reaches about 40%. Subordinate organisms are Chlorophyceae algae (*Halimeda, Microdictyon).* Along the lower drop-off, the coral cover declines rapidly; it reaches levels of about 10% at depths of 15-20 m, but it does not exceed 5% at 35 m . The main builders are *Astreopora, Pachyseris, Favia,* associated with *Montipora, Pocillopora* and *Dysticopora.* The algal flora is composed of *Caulerpa seurati, C. racemosa* and *Halimeda micronesica.* However encrusting forms (*Melobesieae*), which colonize the whole lower drop-off up to 40 m , display the highest degree of coverage (up to 60 %).

Along the forereef zone of the high-energy reefs, coralline algae (*Porolithon onkodes, Lithophyllum sp*) play the main building part. Scleractinian corals, such as *Pocillopora* and *Acropora,* and the hydrocoral *Millepora platyphylla* occupy about 25% of the surface available. The algal *Halimeda* are relatively abundant (cover = 10-15%). From 15 to 30 m , the margin slope (drop-off) is mainly colonized by the corals *Pocillopora, Astreopora* (cover = 15%) and the green algae *Halimeda* and *Caulerpa* (cover = 30-40%).

Seaward of the low-energy reefs, the degree of coral coverage of the spurs varies between 40 and 70% from sea surface to 6 m . Here *Pocillopora* and *Acropora* are dominating. From 6 to 15m, the coral fauna which is chiefly represented by *Porites* and *Synarea,* occupies 25 % of the substrate only.

C. THE DEEPER FOREREEF ZONE

The only sector selected for detailed bathymetric work is off Temao coast (Figure 15). It was mapped up to a depth of 450 m. The most prominent feature is that the margin ends abruptly in a drop of about 300 m; depths of 100 m generally occur less than 100-200m offshore. Along this steep fore-reef slope a few smooth grooves only are observable as indicated by local inflections of contour lines. However a narrow bench extends from depths of 40 to 60 m. With no noticable relief down to 290-310 m where a relatively abrupt ramp connects the upper part of the deeper fore-reef with the distal shelf slope. In marked contrast to its steepness and relatively smooth topography

down to 310 m, the lower part of the deeper fore-reef at the depths of 310-450 m is characterized by a moderate gradient and noticeable relief.The contour patterns indicate well- developed hillocks and depressions on gently dipping (less than 20°) platforms. For instance, a bench extending from 310 to 340m exhibits a number of 15-20 m high hummocks and 8-10 m deep sinks; this bench is irregular in outline : wide amphitheatre-like cavities separate front cape-shaped lobes from another. An escarpment of some thirty metre high (340-345 to 370-375 m) grades into a large, very gently sloping area, broken by high-relief features (30-40 m) and deep basins (20-30 m).

Thus examination of sounding profiles clearly reveals the occurrence of two distinct insular slope zones delimited by the 300 m depth line. The latter may indicate two distinct superimposed reef buildups of Intermediate Tertiary age.

THE SEAWARD MARGIN : INTERPRETATIVE PATTERNS

A. EVOLUTIONARY PATTERN

Like most seaward margins of recent reef tracts, the reef margin of Makatea is steep. Summarizing the very earliest investigations on reefs, Darwin (1842) noted that reefs in many regions possess subvertical drop-offs just seaward. Subsequent profiles and soundings obtained notably from Pacific reefs (Marshall islands : Tracey *et al.*, 1948; Tuamotus : Newell, 1956; Chevalier *et al.*, 1969; Carolines : Tracey *et al.*, 1961) have recorded a "ten-fathom terrace", i.e. a sudden break in slope somewhere between 8-30 m, below which a submarine cliff occurs. The morphology of the upper fore-reef zone is usually as follows: the reef front extends slopeward as a spur-and-groove system to a gently dipping terrace the outer edge of which is at a depth averaging 10 m. The leading edge of this terrace is an abrupt change in slope and the bottom drops, beyond at an average slope of 45° or steeper (Figure 16).

As summarized by James and Ginsburg (1979, p. 153), the topographical features of the upper reef slopes were first regarded as resulting from shallow-water reef growth during subsidence, before Quaternary sea-level changes were known. David *et al.*, (1904) reported some evidence of coral growth on the seaward faces of reefs at depths below the limit of luxuriant coral development. With the subsequent knowledge of the extent of glacially-controlled Pleistocene sea level fluctuations, Daly (1910) postulated that the fore-reef zones are erosional relict features dating from a lower sea level. Likewise, although he did not agree with Daly entirely, Vaughan (1919) interpreted the reef wall as being the result of erosion during low sea stands. Recently, James and Ginsburg (op. cit.) studying the seaward margin of Belize barrier and atoll reefs extended the theory of discontinuous lateral accretion first suggested by David *et al.*, (1904). They concluded that this style of accretion is an universal phenomenon.

Investigations on some French Polynesian seaward margins furnished data indicating that this fundamental problem is less simplistic than was previously expected. Underwater observations and drilling through the outer rims of atolls and barrier reefs strongly support the fact that submerged terraces and the adjacent reef walls could either be an equilibrium feature related to the reef-building corals and wave and current action, or be erosional related to a lower sea level (Figure 17).

On the northern barrier reef face of Moorea island, the outer slope displays a well differentiated terrace about 20 m wide, at a depth of 15-16 m, below the upper spur-and-grooves system. This terrace is connected outward to a lower buttress system. A borehole which was positioned some 50 m behind the reef front, penetrated

up to 20 m of unconsolidated to slightly cemented material of Holocene age, without reaching any unconformity surface, i.e. pre-Holocene constructional or erosional platform (Montaggioni and Delibrias, 1986). This demonstrates that this 15-16 m terrace is not erosional; it is a current induced feature as suggested by Jaubert *et al.* (1976), in accordance with the hydrodynamic model of Roberts *et al.* (1975). A similar conclusion arises from studies of nearby Tahitian outer reef slopes (Montaggioni, unpublished data). In these cases, the upper fore-reef zone appears to be the result of a significant upward and lateral accretion from a newly buried, preexisting reef surface, during the Holocene sea level rise.

On the atolls of Mataiva (Montaggioni, pers. observ.) and Mururoa (Chevalier *et al.*, 1969), the outer slopes are broken by an upper terrace lying respectively 6 and 8-11 m deep, which follows a small scarp 2-4 m high. The numerous holes drilled on these two sites (Mataiva : Pirazzoli and Montaggioni, 1986 ; Mururoa : Repellin, 1975; Buigues, 1983) give evidence that this terrace is the top of a former (Pleistocene or older) reef body in part subaerially eroded (equivalent to the Thurber solution disconformity of the limestone column). A similar origin is expected for the terraces at 6 and 12 m below sea level which have been reported respectively from Tikehau atoll (Faure, pers. comm.) and Takapoto atoll (Montaggioni, pers. observ.). In these cases, significant reef accretion seems to have been restricted to the upward growth of the upper spur-and-groove system, while the submerged platform and adjacent reef wall are partly eroded, coral-built relict reliefs on which recent corals have grown as thin veneers (Figure 18).

In conclusion, the present morphology of the outer reef margins in French Polynesia and consequently, in Makatea, is probably a reflection of both erosional and accretionary effects. The coincidence of the step in morphology at depths of 6-16 m reflects either the upper level of reef growth during former sea level high stands prior to subaerial exposure and alteration, or an interaction of current with morphology during reef growth. The variability of the depth at which the submarine terraces are at present recorded, is chiefly a function of the local tectonic history prior to the Holocene marine transgression. For instance, in the northwestern Tuamotu region, the late Pleistocene reef surfaces lie between a few metres above present sea level and about ten metres below, while, in the Society high volcanic islands, they lie at depths over to 30 m. The first ones belong to a relatively uplifting area, while the second are affected by an active subsidence, caused by thermal contraction of the underlying crust.

B. DISTRIBUTIONAL PATTERN OF BENTHIC COMMUNITIES

1. Flora

Generally the uppermost parts of the reef margin are preferentially colonized by encrusting coralline algae (*Porolithon, Lithophyllum*). According to wave energy, these algae make up either a thin veneer (sheltered areas) or a well-developed ridge (exposed areas) similar to those classically described from other Polynesian atolls (Denizot, 1969). At the base of the cliffs, beside Rhodophyceae, a number of other algae (*Microdictyon, Neomeris, Caulerpa, Halimeda, Avrainvillea*) typical of the reef edges of atolls (Chevalier *et al.*, 1969; Denizot, 1969, 1972) occur widely. Along the high-energy fore-reef zone to 10 m, the coralline algal surface coverage reaches up to 60%, while that of *Halimeda* species does not exceed 15%. From 10 to 40 m , *Halimeda* and *Caulerpa* flourish (40% of the substrate).

The outer parts of the reef flat zone exhibit highly variable specific diversity. The total algal cover can reach up to 80%, but the related populations only form a very close-cropped turf. The brown alga *Lobophora variegata* forms a continuous peripheral

belt. The other floristic elements (*Giffordia sp., Liagora ceranoïdes, Hassalia byssoïdes, Halimeda opuntia, H. taenicola, Caulerpa cupressoïdes, C. urvilliana, Dictyospheria favulosa,* Rhodymenials) are subordinate, colonizing the substrates here and there. Coralline algae are still present. Among soft algae, the most common forms belong to the following genera : *Halimeda, Caulerpa, Microdictyon, Amphiroa* and *Turbinaria*.

In contrast, the inner parts of the reef flat zone display more monotonous floristic communities. The substrate is widely occupied by turfs of *Cladophora* whose coverage increase with confined conditions. Locally, in exposed areas, cyanophyte films develop. Thus all the substrates which undergo long periods of emergence (beach-rocks) are colonized by the blue-green algae *Hassalia* and *Entophysalis*. However no stromatolite-like feature has been observed at Makatea, while protostromatolitic deposits occur on several Polynesian atolls (Rangiroa, Mataiva, Mururoa,...) (Bourrouilh-Le Jan, 1977 ; Montaggioni, pers. observ.; Trichet, pers. com.; Defarge, 1983). This may be ascribed both to the unevenness of the reef flat surfaces and the coarseness of reef flat sediments. In some areas four species of brown algae (*Turbinaria ornata, Chnoospora minima, Ectocarpus breviarticulatus, Hydroclathrus clathratus*) produce high biomasses. This is a confusing particularity of Makatea since the brown algae and these two species of *Turbinaria* and *Chnoospora* are very uncommon on the other Tuamotu atolls (Seurat, 1934; Doty, 1954; Denizot, 1971, 1972).

2. Fauna

The reef-building scleractinians and hydrocorals reported from Makatea belong to about 15 genera and more than 35 species; they are the same as those described in the majority of Tuamotu atolls (Chevalier, 1979). The reef flat zone has a very low coverage (less than 5%) and only show stunted colonies. The dominant forms are *Acropora rotumana* in sheltered areas, *Porites cf. compressa* and *Montastrea curta* in exposed areas. In contrast, coral communities flourish along the forereef zone; their distributional patterns are dependent upon water energy and/or depth. At a depth of 10 m, in higher energy zones, coral cover does not exceed 25%, while it can reach 40-70% in lower energy slopes. The dominant species is *Pocillopora verrucosa,* associated with several species of *Acropora, Porites* and, locally, *Millepora platyphylla.* The 10-25 m zone is dominated by *Pocillopora verrucosa* and *P. eydouxi.* The lower parts of the shollower fore-reef zone studied (25-40 m deep) are characterized by high amount of *Astreopora myriophthalma* and high degrees of coral coverage (higher than 80%).

The composition of the molluscan fauna of Makatea is relatively similar to those mentioned from various Tuamotu islands (Salvat, 1979; Richard, 1982). On the algal ridges and reef fronts, the dominant species are *Patella flexuosa, Turbo setosus, Drupa morum* and *D. ricinus*. The reef flat zone is inhabited by dense populations of molluscs mainly including *Mitra litterata, M. pauperculata, M. granulata, Drupa cancellata, Conus sponsalis, C. lividus, Puperita reticulata, Bursa bufonia, Tridacna maxima, Thais armigera, Cypraea moneta, C. caput-serpentis.* Emerged beach-rocks are colonized by *Nerita plicata, Tectarius grandinatus, Thais aculeatus* and *Littorina coccinea.* Along the poorly developed reef areas, the zonation of molluscs reminds successively of those of the algal ridges and beach-rocks; from the upper parts of the outer slopes to the cliffwalls, *Haliotis pulcherrima, Drupa ricinus, D. morum, Turbo setosus, Patelloida conoidalis, Thais aculeatus, Nerita plicata* and *Littorina coccinea* can be found.

At Makatea, as on the majority of the Tuamotu reefs, the specific diversity is higher in the sheltered areas, but the highest amounts in individuals occur in the most

exposed areas. The families showing the highest specific richness are omnivorous (Cypraeidae : 20 species) or carnivorous (Muricidae : 15), but those showing the highest concentration in individuals (Littorinidae, Cerithiidae) are grass-eating.

With 121 species collected, the molluscan fauna is here assumed to be relatively poor, by comparison with those described from the outer rims of the other Tuamotu atolls.

On the whole flat reef zone, echinoderms are not very common, except for the echinid *Echinometra mathaei* and the holothurid *Holothuria atra*. Moreover, the echinid *Colobocentrotus pedifer* is highly frequent, locally associated with *Heterocentrotus mamillatus* in the high energy zones of this island, whereas it is generally scarce in the Tuamotu archipelago (Richard and Salvat, pers. obs.).

CONCLUSIONS

Makatea island has a singular submarine morphology whose major features have been controlled by global and regional events (eustasy, climate and uplifting) mostly during Quaternary times .

The main ecological characteristics of the seaward margin are the monotony and paucity of fauna and the wide-spreading of fleshy brown algae.

The algal flora has to be regarded as a mixture of species typical of high volcanic islands (*Pheophyceae*) and species typical of low carbonate islands (*Chlorophyceae*).

While the coral colonies living on reef flats are sparce, a large part of the shallower forereef zone is characterized by the richness and vitality of coral communities. The associated macrofauna (molluscs, echinoderms) is poorer than those commonly observed along the outer margins of Polynesian atolls. This may be due to the reduction of available biotopes and the long-term exposure of some reef flat areas.

Makatea seems to be a very special island within the Tuamotu archipelago and although its main biological features of which cannot be used as a model for nearby Polynesian islands, it is a geologically very interesting experimental field since it retains about 25 millions year-long history of Pacific near surface waters. Future research on Makatea island will have to focus on Miocene reef deposits : nature and distribution of main builders, reef growth and global changes, early diagenesis and phosphatogenesis.

ACKNOWLEDGEMENTS

Gratitude is due to the Service de l'Equipement and Administration Civile des Iles Tuamotus (Tahiti, Papeete) for their assistance and logistic support. The field help of natives was greatly appreciated.

Special thanks are extended to Dr MacIntyre for reviewing this manuscript.

DEDICATION

This work is dedicated to our colleague and friend Marie-Héléne SACHET, formerly Curator of the Botanical Department, who died in July 1986

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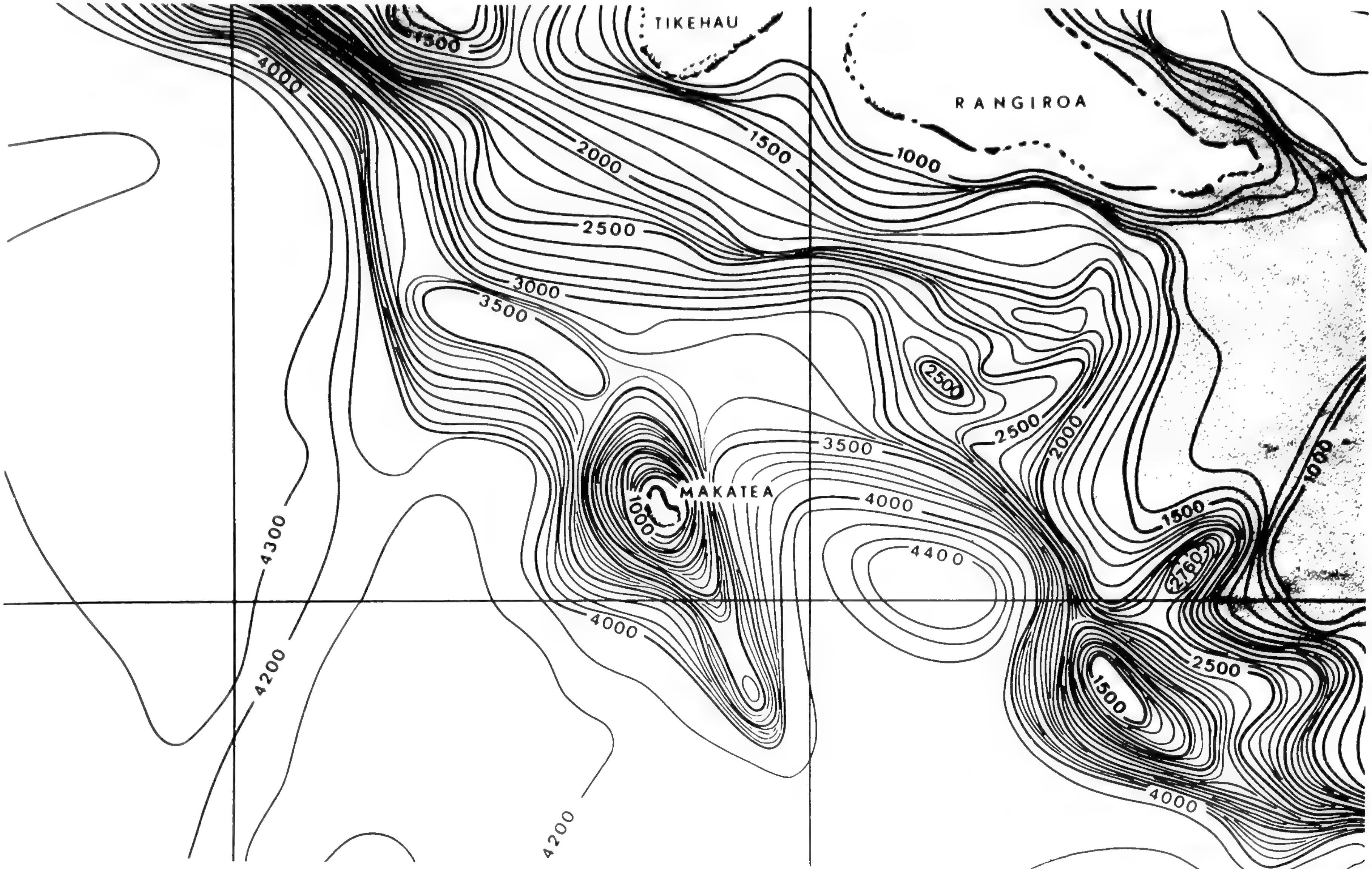


Figure 1 .- Bathymetric chart of the northwestern part of the Tuamotu archipelago with the area of Makatea island (depth contours in metres) (after Monti, 1974).

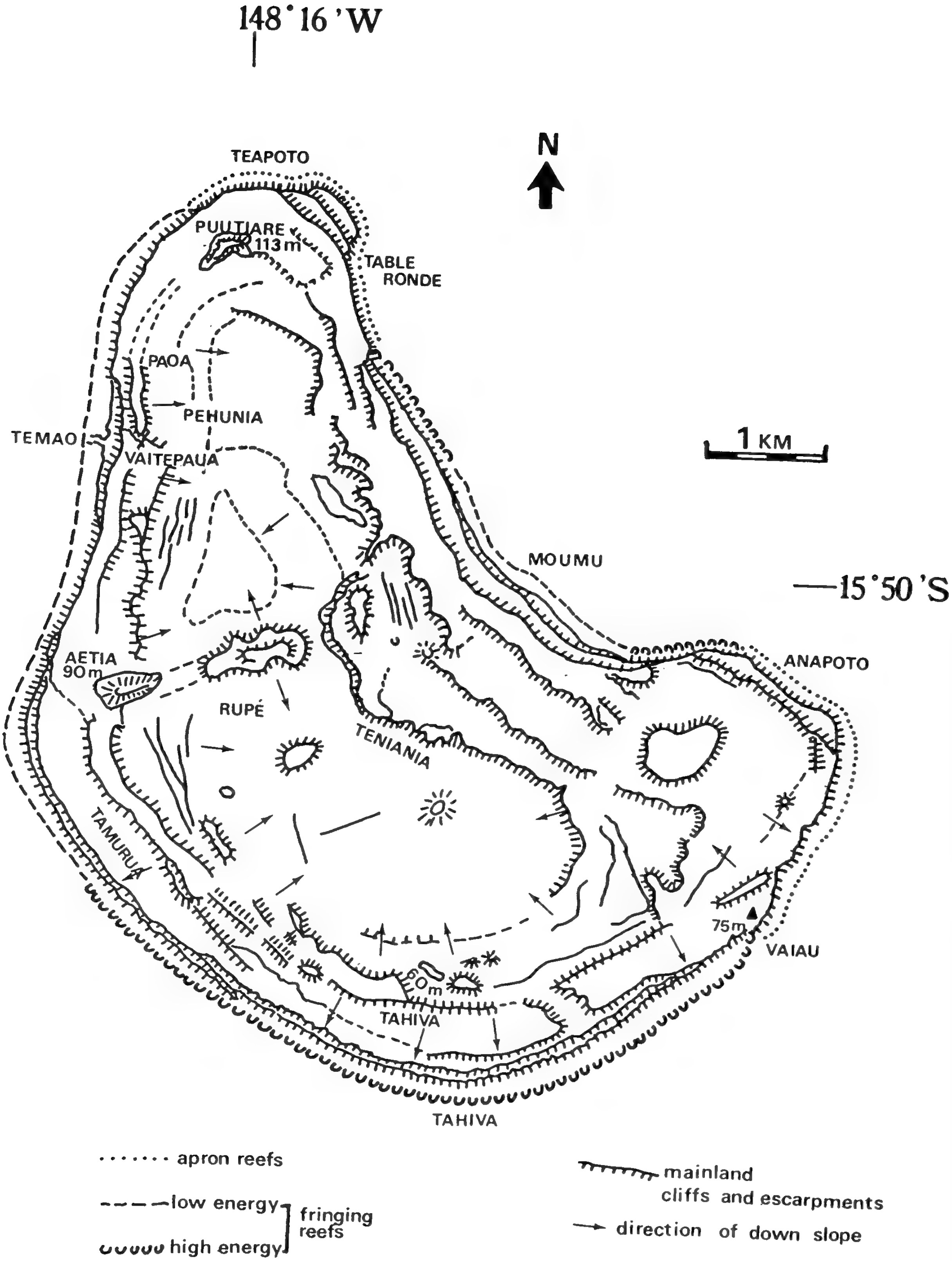


Figure 2 .- A schematic map illustrating the main geomorphologic characteristics of Makatea island (modified from Bourrouilh-Le Jan, 1977, and Montaggioni *et al.*, 1985 b).

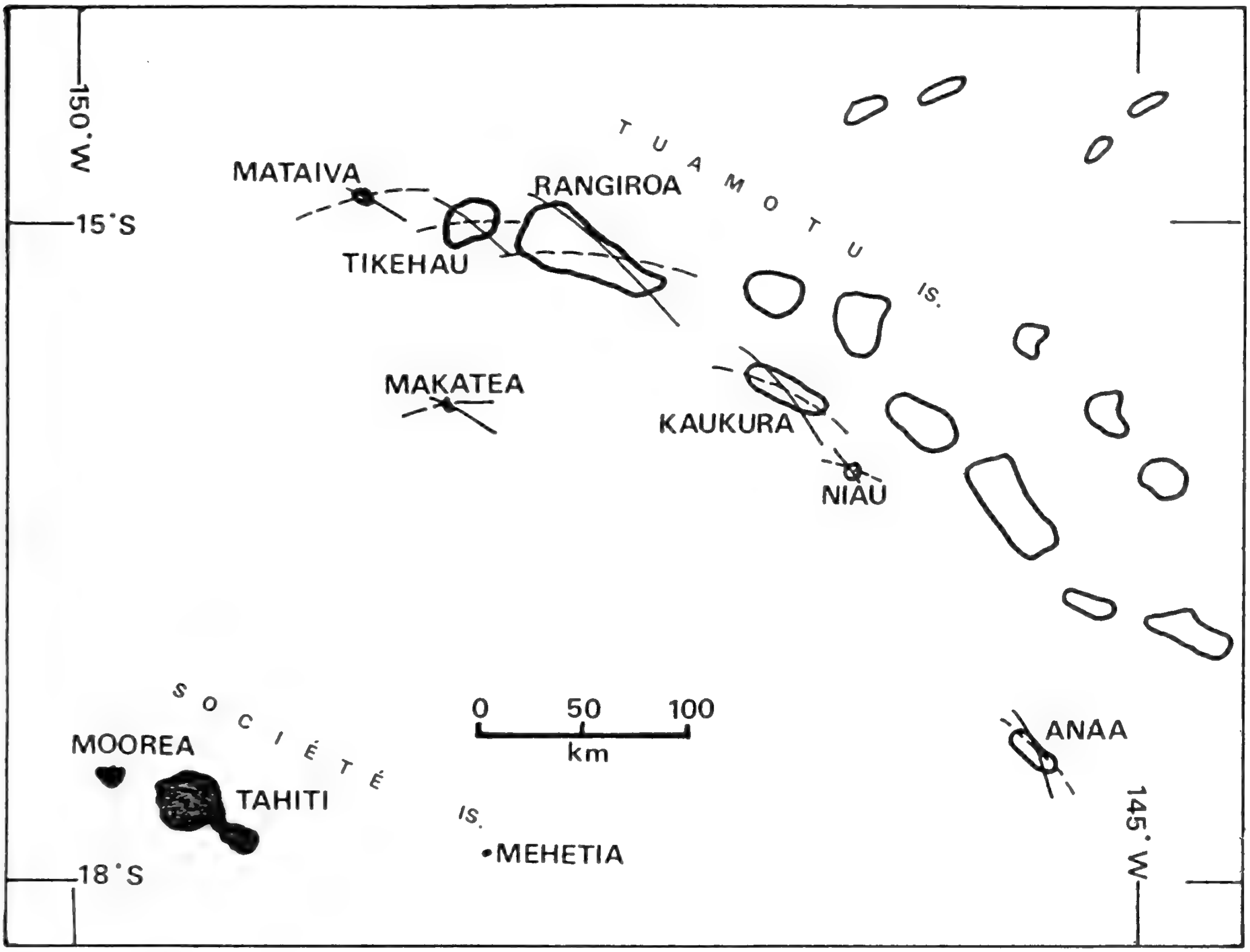


Figure 3 .- Atoll uplift in the nortwestern Tuamotu area. Uplift contours drawn through atolls correspond to the flexure from loading by Tahiti (solid arcs) and Mehetia (dashed arcs).
Simplified from Mc Nutt and Menard (1978).

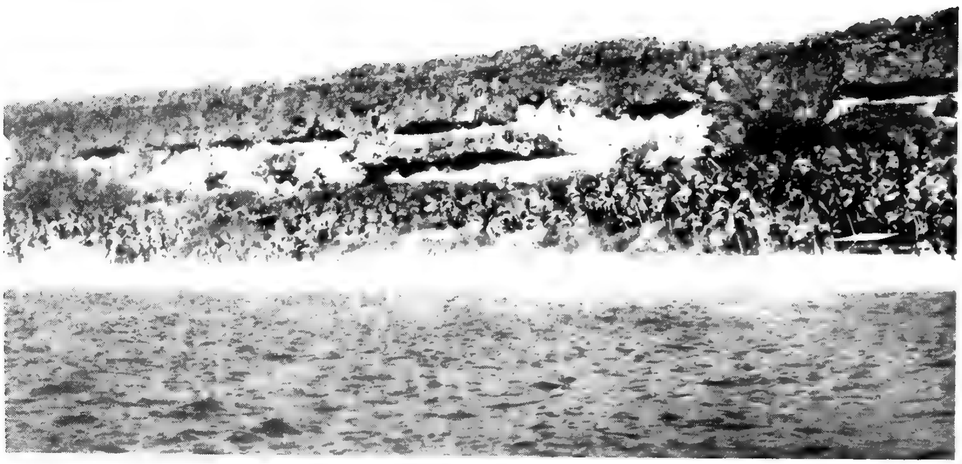


Figure 4 - General view of the northeastern cliff bounded by narrow apron reefs and beaches (photo L. Montaggioni)

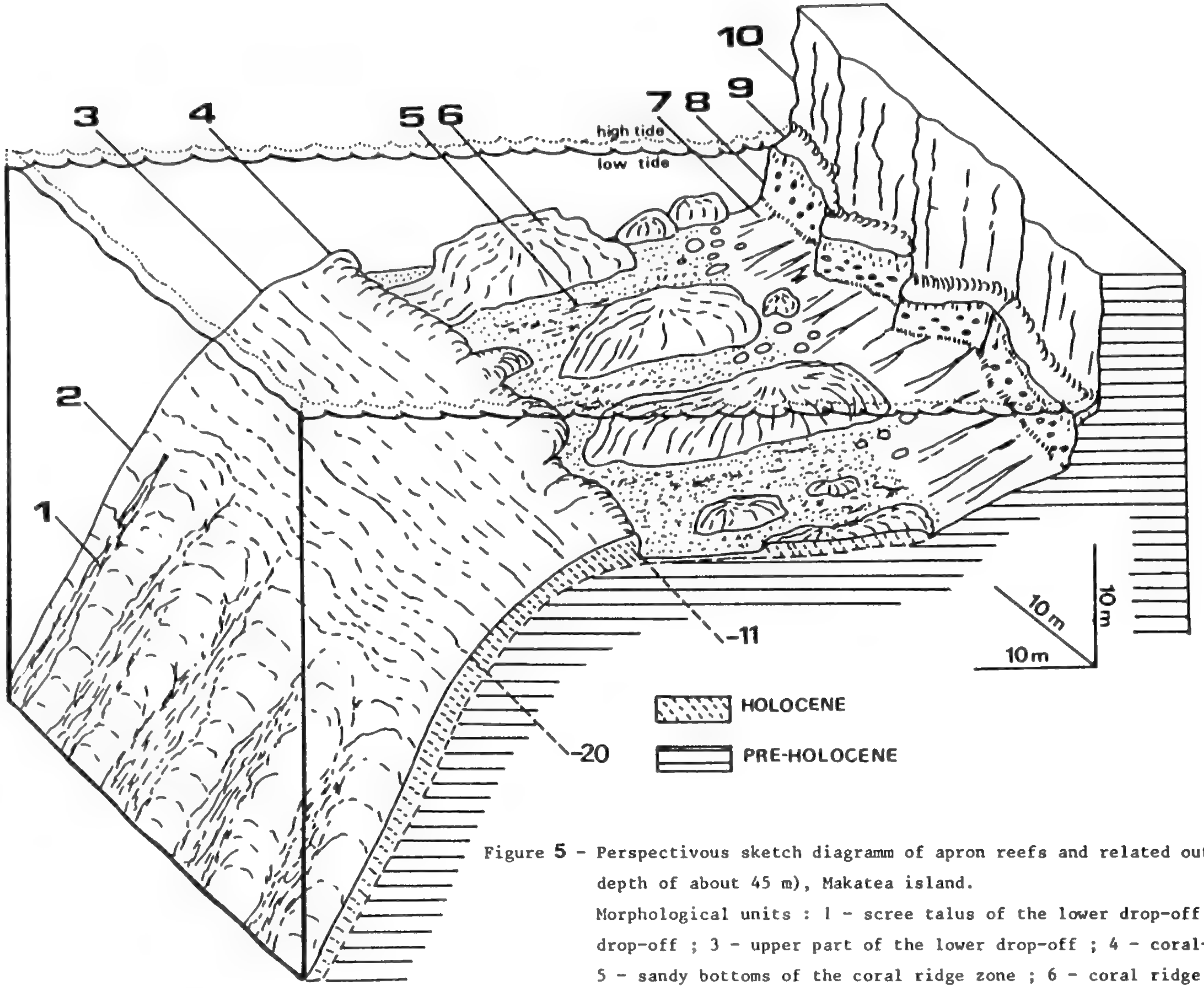


Figure 5 - Perspectivous sketch diagramm of apron reefs and related outer slopes (to the depth of about 45 m), Makatea island.
Morphological units : 1 - scree talus of the lower drop-off ; 2 - coral-built drop-off ; 3 - upper part of the lower drop-off ; 4 - coral-built step ; 5 - sandy bottoms of the coral ridge zone ; 6 - coral ridge ; 7 - furrowed platform ; 8 - upper drop-off ; 9 - apron reef flat ; 10 - cliff.
The depth of 11 m indicates the position of the break in slope.

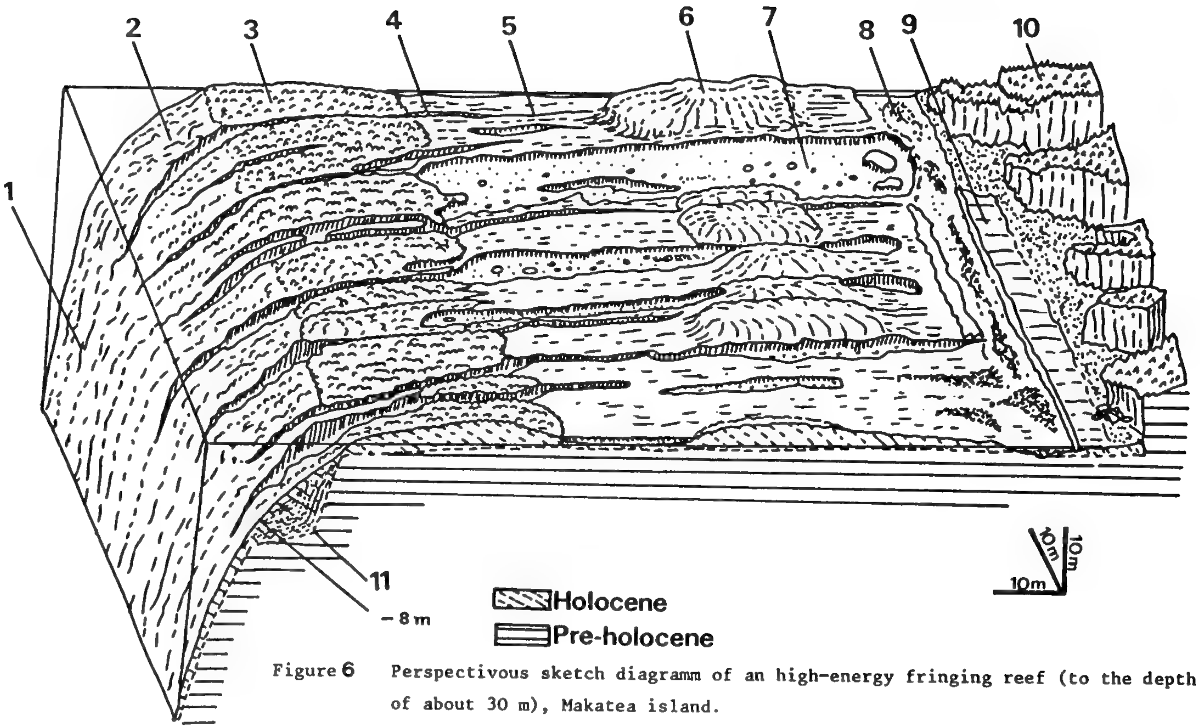


Figure 6 Perspectivous sketch diagramm of an high-energy fringing reef (to the depth of about 30 m), Makatea island.
Morphological units : 1 - outer drop-off ; 2 - spur-and-groove system ; 3 - algal ridge ; 4 - reef flat groove ; 5 - reef flat flagstone ; 6 - conglomeratic crag ; 7 - erosional basin from the reef flat flagstone ; 8 - backreef channel ; 9 - beach-rocks ; 10 - cliff ; 11 - hypothetic submarine platform of Pleistocene age. The depth of 8 m indicates the position of the break in slope.

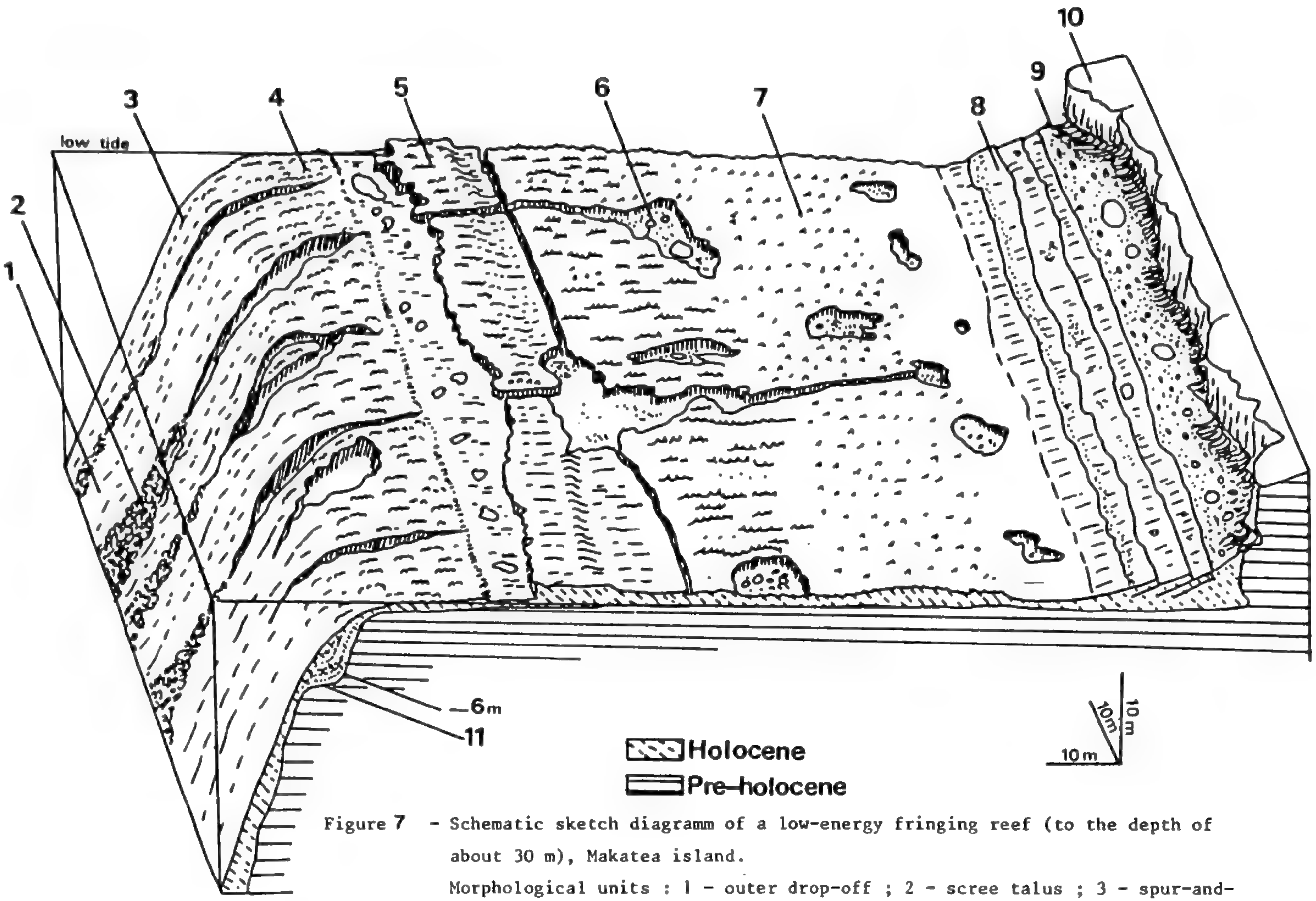


Figure 7 - Schematic sketch diagramm of a low-energy fringing reef (to the depth of about 30 m), Makatea island.
Morphological units : 1 - outer drop-off ; 2 - scree talus ; 3 - spur-and-groove system ; 4 - outer glacis ; 5 - micro cliff and erosional step ; 6 - erosional basin from the reef flat flagstone ; 7 - reef flat flagstone ; 8 - exposed beach-rocks ; 9 - gravel-and-sand-grained beach ; 10 - cliff ; 11 - hypothetic submarine platform of Pleistocene age. The depth of 6 m indicates the position of the break in slope.

Figure 8 - General view of the northwestern margin with a low-energy reef flat zone (photo L. Montaggioni)

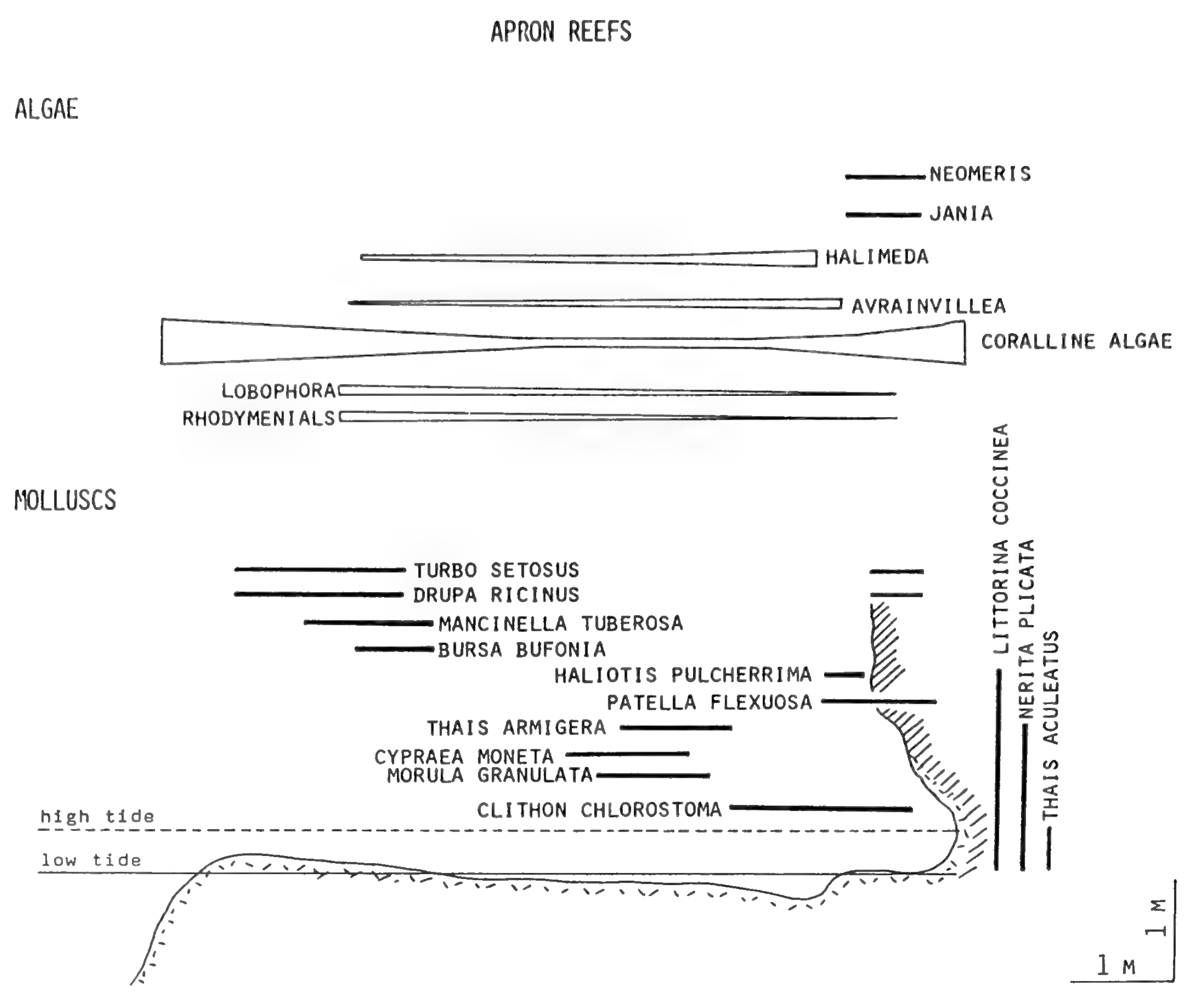


FIGURE 9 - DISTRIBUTIONAL PATTERNS OF THE MAIN ALGAL GENERA OR FAMILIES AND MOLLUSCAN SPECIES ON THE APRON REEFS OF MAKATEA ISLAND

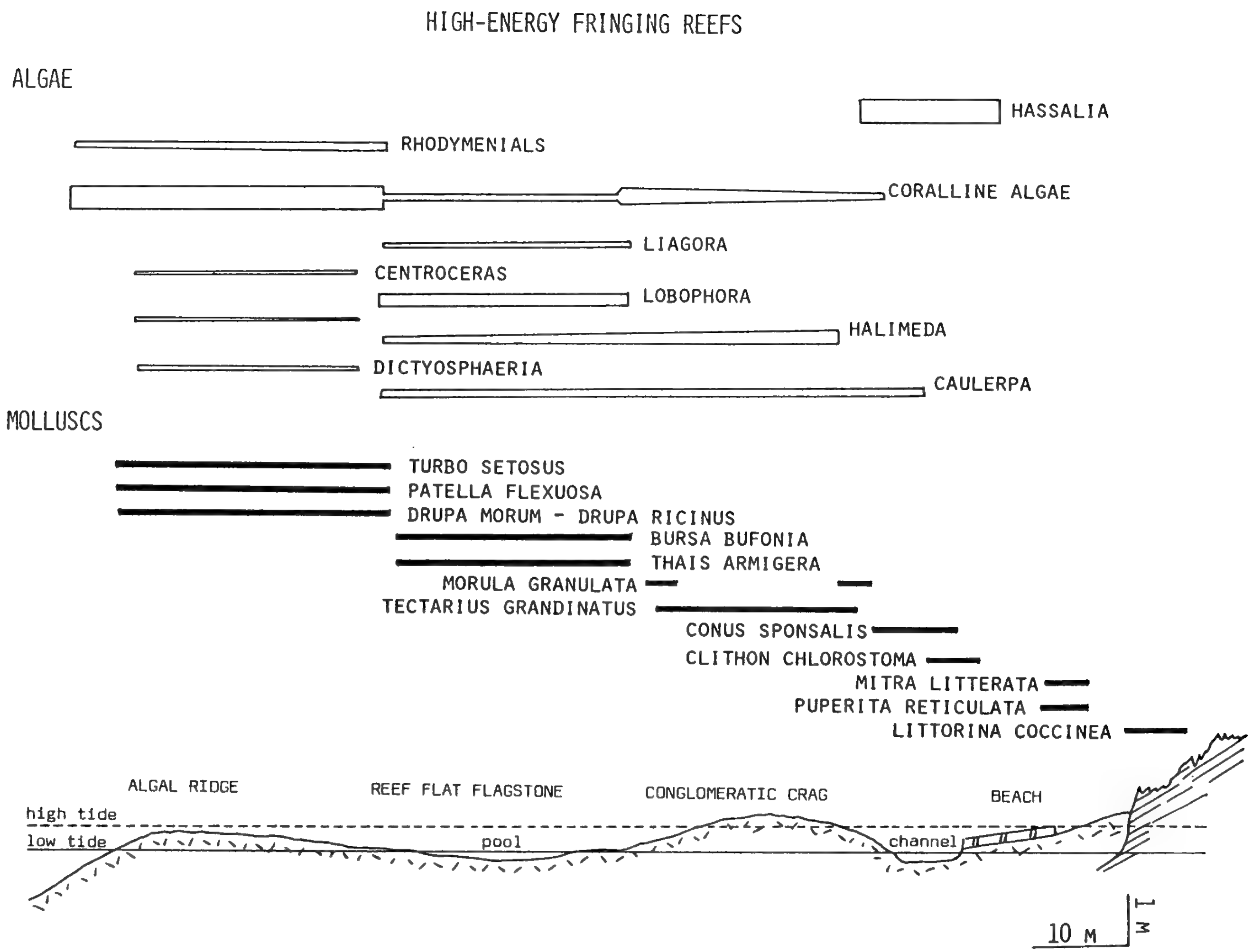


FIGURE **10** - DISTRIBUTIONAL PATTERNS OF THE MAIN ALGAL GENERA OR FAMILIES AND MOLLUSCAN SPECIES ON THE HIGH-ENERGY FRINGING REEFS OF MAKATEA ISLAND

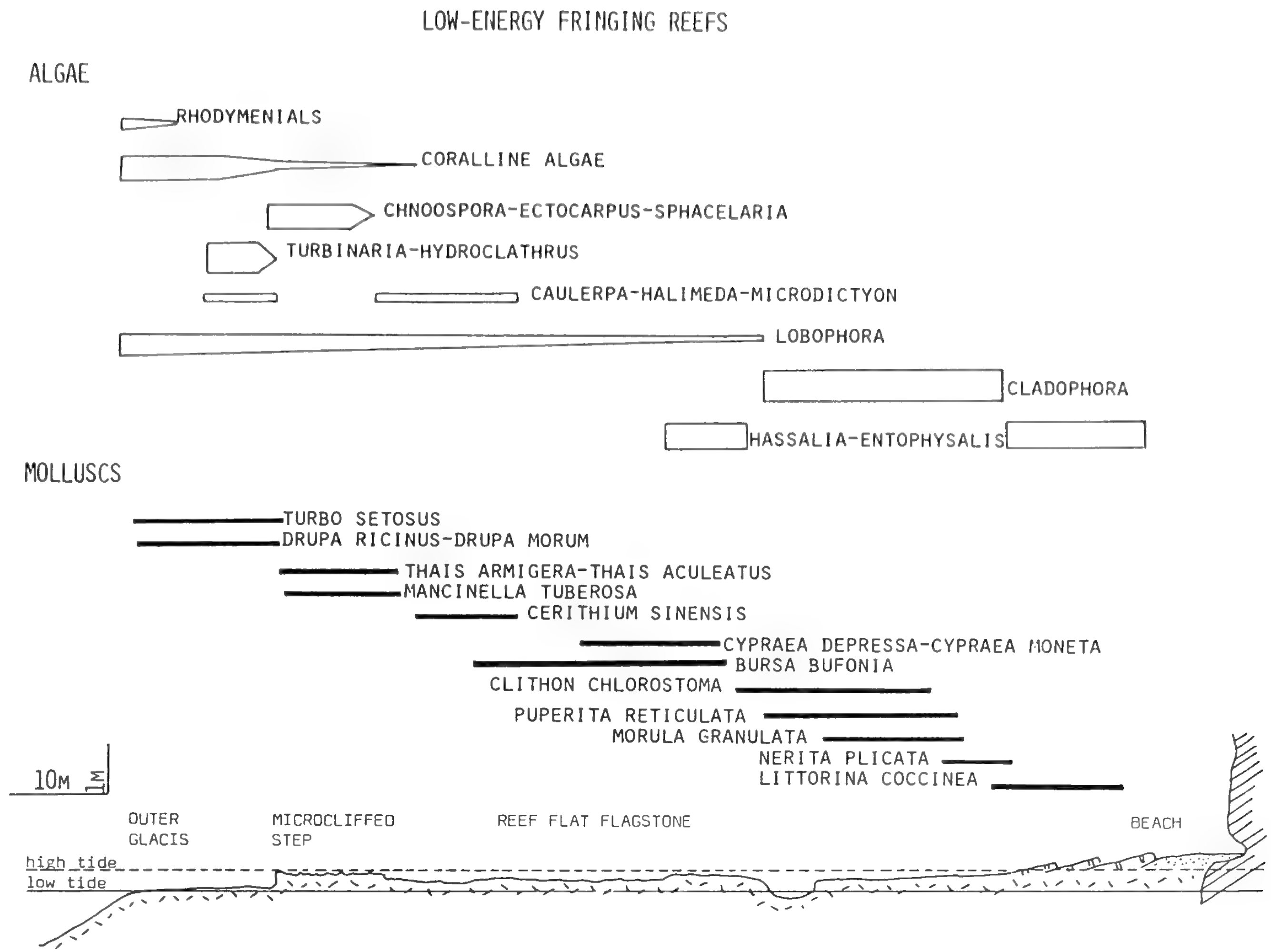
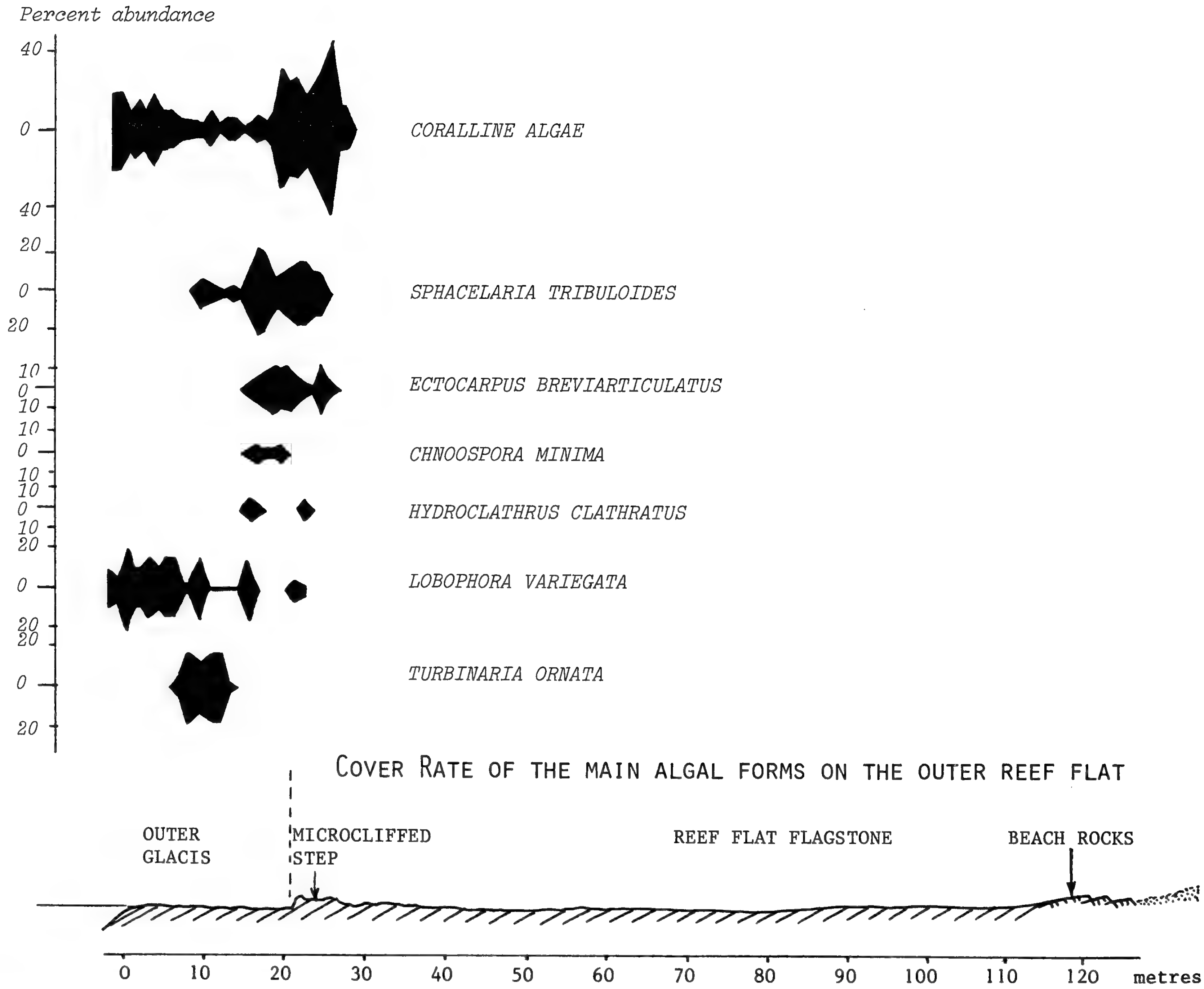


FIGURE 11 - DISTRIBUTIONAL PATTERNS OF THE MAIN ALGAL GENERA OR FAMILIES AND MOLLUSCAN SPECIES ON THE LOW-ENERGY FRINGING REEFS OF MAKATEA ISLAND



COVER RATE OF THE MAIN ALGAL FORMS ON THE OUTER REEF FLAT

FIGURE 12

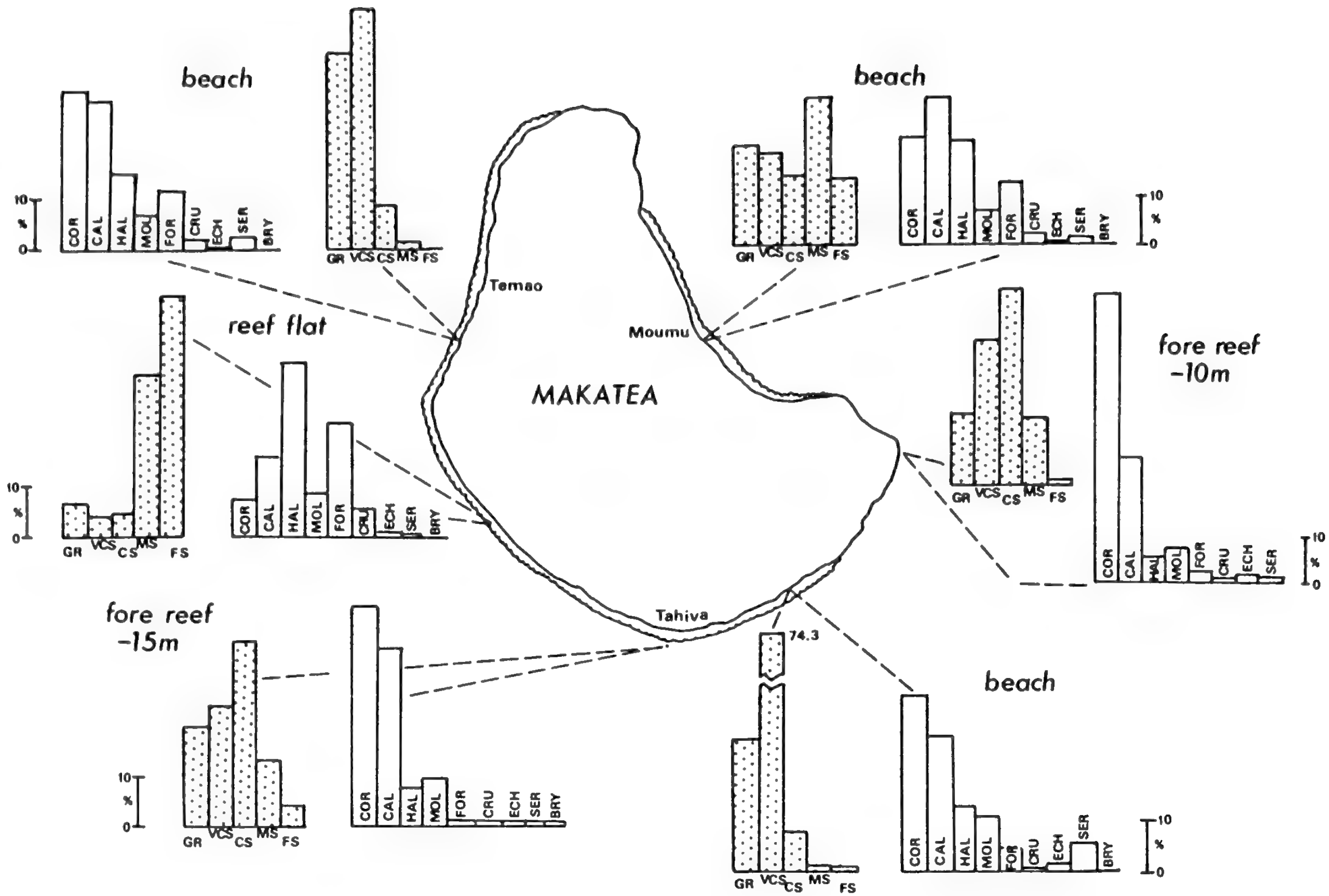


Figure 13 - Frequency histograms of selected sediment types illustrating the occurrence of distinct size classes (GR = granules ; VCS = very coarse sands ; CS = coarse sands ; MZ = medium sands ; FS = fine and very fine sands) and of constituent categories (COR = corals ; CAL = coralline algae ; HAL = *Halimeda* ; MOL = molluscs ; FOR = foraminifers ; CRU = crustaceans ; ECH = echinoderms ; SER = Serpulids ; BRY = bryozoans), from various reefal unconsolidated bodies of Makatea island.

SHALLOWER FOREREEF PROFILE IN A FAULT-CONTROLLED AREA

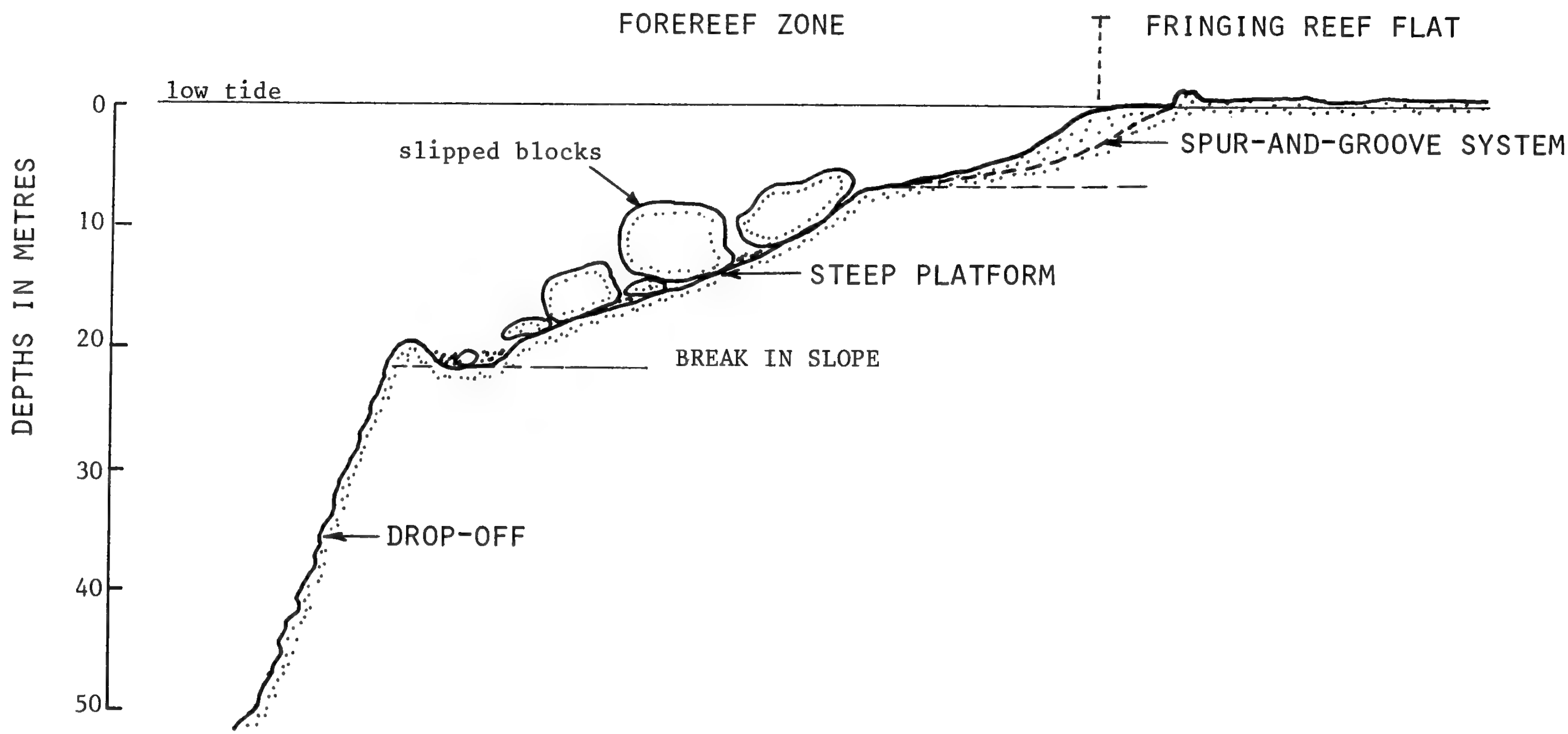


FIGURE 14

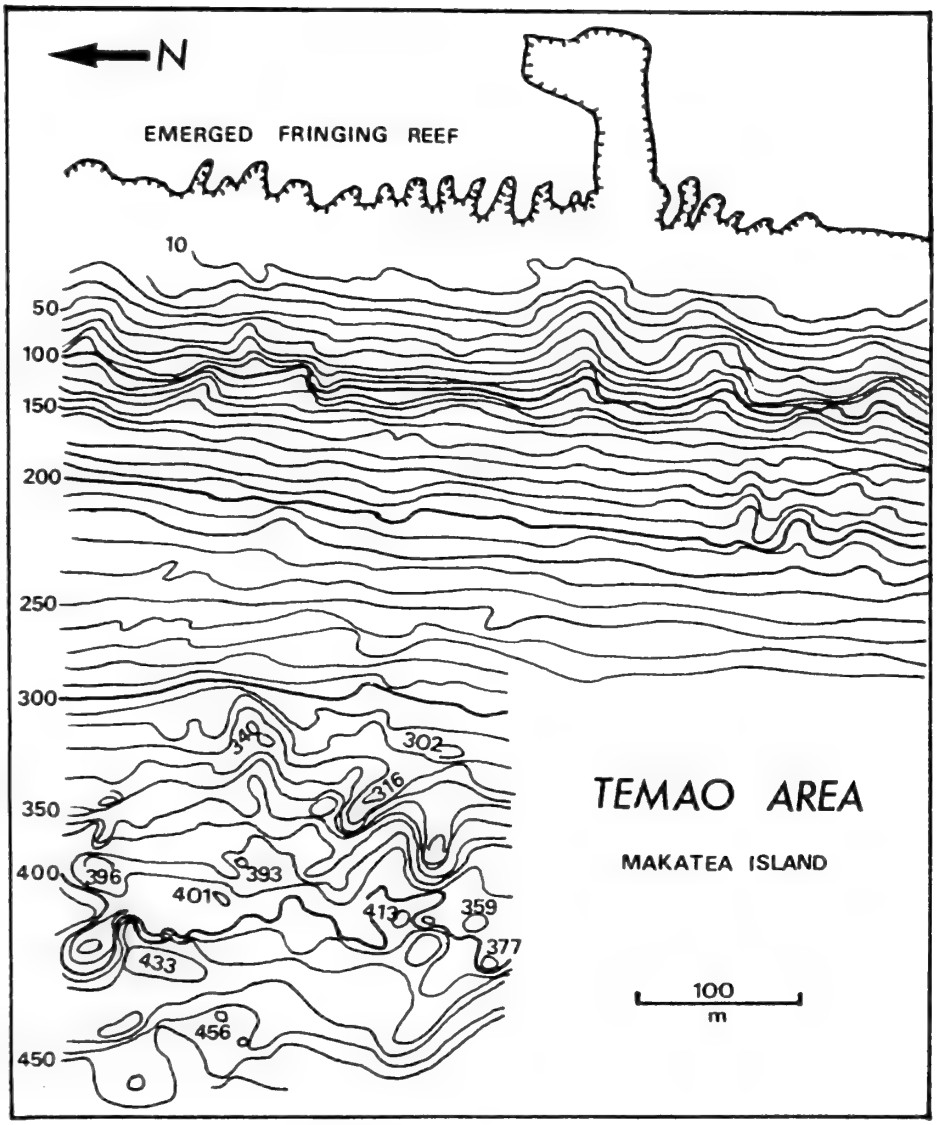


Figure 15 .- A bathymetric chart of the western seaward margin of Makatea island, Temao area (After Doumenge, 1963).

REPRESENTATIVE PROFILES ACROSS THE SEAWARD MARGIN AT MAKATEA, MATAIVA, MURUROA AND BIKINI, CONSTRUCTED FROM DEPTH SOUNDINGS (MAKATEA: DOUMENGE, 1963; MATAIVA: DELESALLE, PERS. COMM.; MURUROA: CHEVALIER ET AL., 1969; BIKINI: EMERY *ET AL.*, 1954)

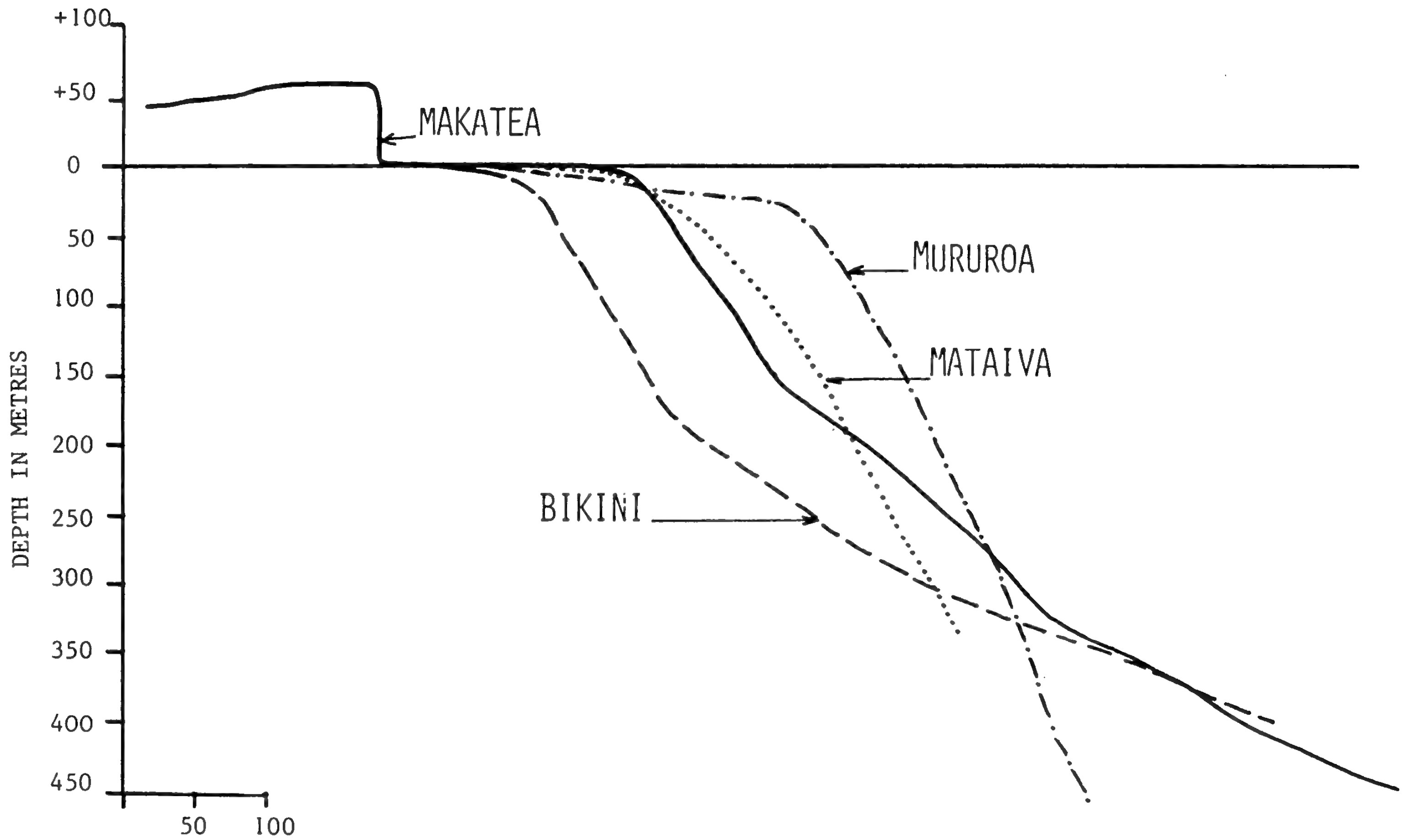


FIGURE **16**

REPRESENTATIVE PROFILES ACROSS THE UPPER PARTS OF THE SEAWARD MARGINS FROM A NUMBER OF FRENCH POLYNESIAN ATOLLS AND REEFS , CONSTRUCTED FROM UNDERWATER OBSERVATIONS (MAKATEA: MONTAGGIONI *ET AL.*, 1984; TAKAPOTO, MOOREA, MATAIVA: MONTAGGIONI, PERS. OBSV.; TIKEHAU: FAURE, PERS. COMM.; MURUROA: CHEVALIER *ET AL.*, 1969)

T terrace BS break in slope

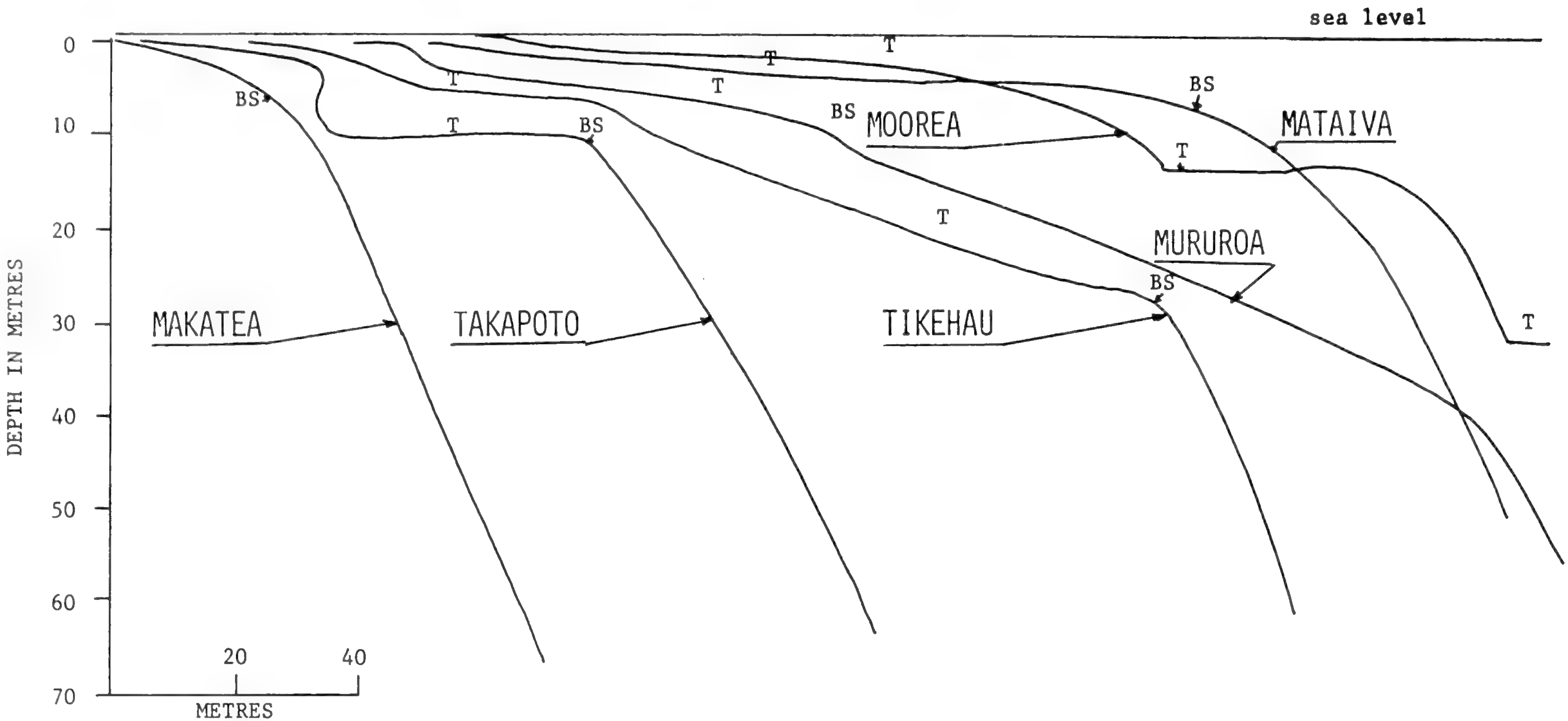
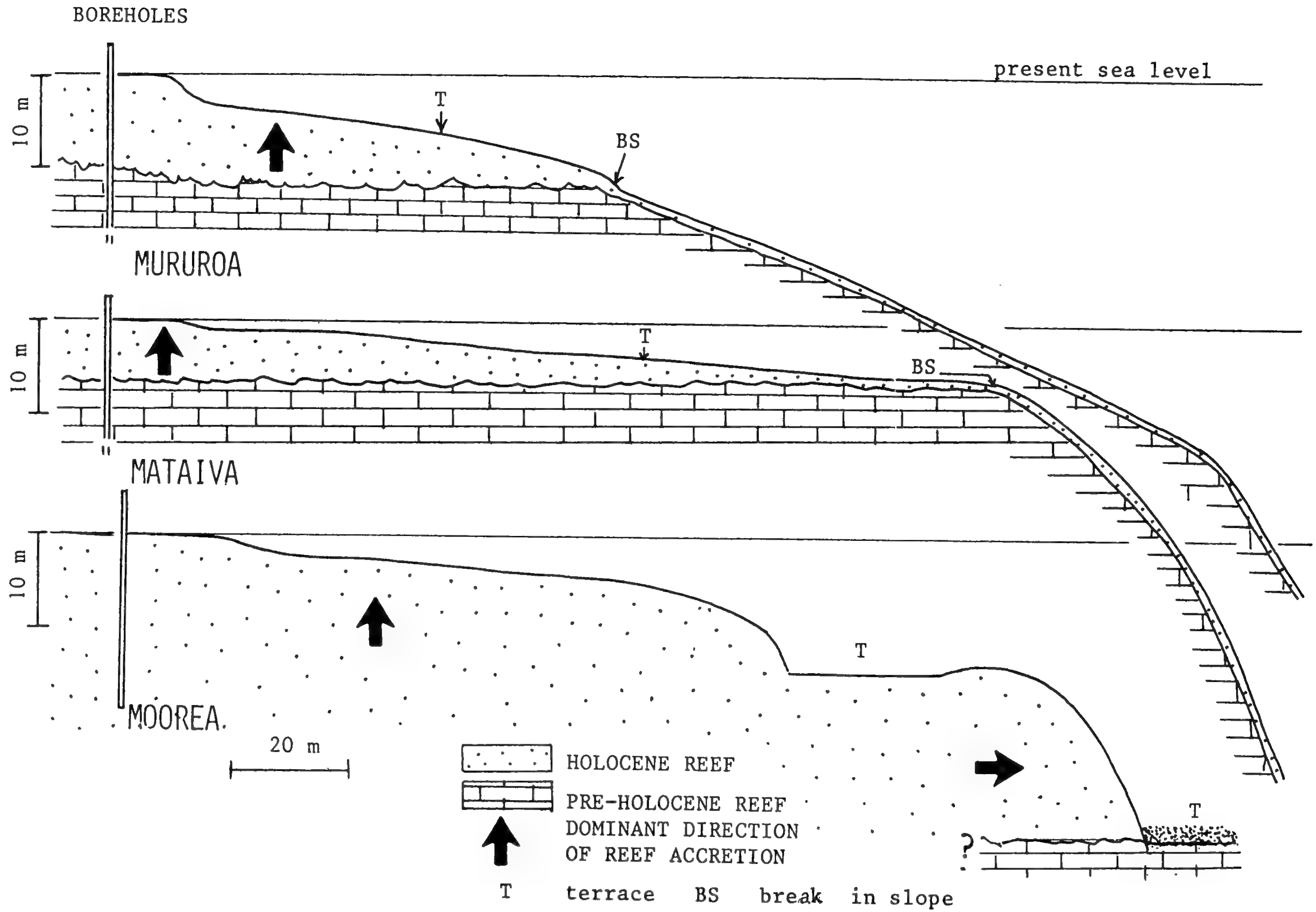


FIGURE 17



INTERPRETATIVE CROSS-SECTION OF THE UPPER PARTS OF THE SEAWARD MARGINS, FRENCH POLYNESIA REEFS, CONSTRUCTED FROM UNDERWATER OBSERVATIONS AND DRILLING

FIGURE **18**

ATOLL RESEARCH BULLETIN

NO. 300

RECENT CHANGES IN THE AVIFAUNA OF MAKATEA ISLAND (TUAMOTUS, CENTRAL PACIFIC)

BY

JEAN-CLAUDE THIBAULT AND ISABELLE GUYOT

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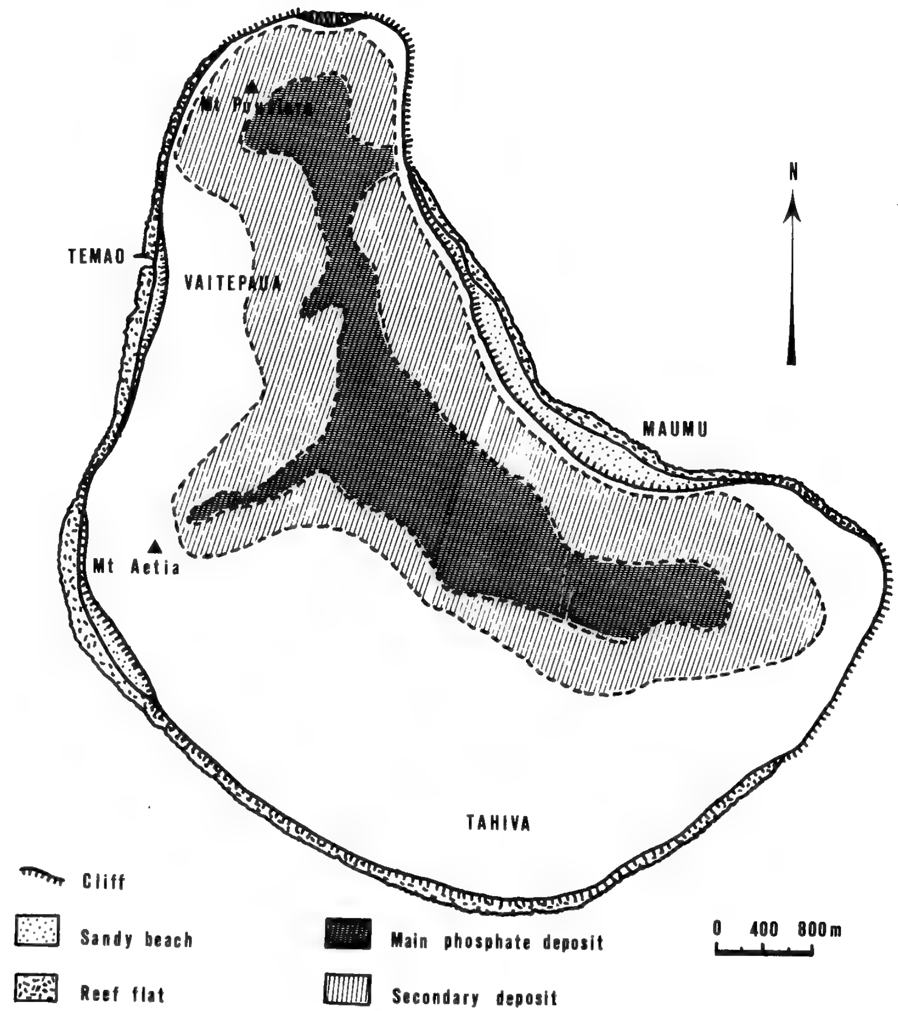

Fig. 1 : Makatea Island and the phosphate mining areas in the past

RECENT CHANGES IN THE AVIFAUNA OF MAKATEA ISLAND (TUAMOTUS, CENTRAL PACIFIC)

BY

JEAN-CLAUDE THIBAULT AND ISABELLE GUYOT

INTRODUCTION

Makatea (148°15'W, 15°50'S) belongs to the Tuamotu archipelago and is situated about 240 kilometers north-east of Tahiti. It is an uplifted coral island surrounded by cliffs ranging from 5 to 70 meters in height. It is 9 km long and 5.5 wide and has an area of about 28 sq.km. The island has a plateau-like surface with Mt Puutiare (111 m) and Mt Aetia (90 m) as highest points. Data on the climate are fragmentary. Precipitations are less important than in the Society Islands with a yearly mean of 1.700 mm (FLORENCE 1982). The geomorphology is complex (see MONTAGGIONI 1985). Its main characteristic was its easily accessible phosphate deposits found at the bottom of small depressions. Tricalcic phosphate was elaborated from the action of rainwater in coral limestone and dejections of birds (BOUZAT 1986). The human population is nowadays about 30 inhabitants whereas 3.000 people were living on Makatea in 1962, when phosphate was mined (DOUMENGE 1963).

The rich flora, compared to the atolls, contains several endemic plants. Among them is a palm tree Pritchardia vuyltekeana. FLORENCE (1982) distinguishes three different plant communities:

- coastal community (Argusia argentea, Scaevola sericea, Cordia subcordata, Hibiscus tiliaceus, Guettarda speciosa, Morindia citrifolia, Pandanus tectorius...),

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- forest community of the plateau (Homalium mouo, Pisonia grandis, Xylosma suaveolens, Pandanus tectorius, Alysia scandens, Allophyllus ternatus, Rapanea ovalis...),
- secondary groves of the mined area (Morindia citrifolia, Guettarda speciosa...). In the latter area, formerly logged, we notice a vigorous recolonization by the vegetation.

This note presents the changes in the avifauna of Makatea during the XIX and XXth centuries.

MATERIAL AND METHODS

The island was first mentioned by Roggeveen in 1722 (JOURDAIN 1970), but visits became regular only during the XIXth century. An evangelist of the "London Missionary Society" settled down in 1829 (NEWBURY 1986), which supposes that exchanges with the outside were regular at that time. This probably explains the presence of bird specimens collected outside the Scientific Expeditions (e.g. description of Ptilinopus purpuratus chalcurus in 1859 by GRAY).

The present paper is based on the data collected during eight visits between 1839 and 1987. Time between these visits varied from 3 to 60 years. The visits were short (from a few hours to several weeks). By comparing the list of species observed or collected each time, it is possible to follow the changes that occured in the composition of the avifauna. Some visits were however too short to give accurate estimates of species composition. This is alas the case of the first one in 1839 (PEALE 1848) which could have informed us about the composition of the Makatea avifauna at a time when many extinctions occured in the Polynesian avifauna following the arrival of the Europeans (introduction for instance of new predators). We have to wait until 1901 (SEALE MS) to have a reliable reference of the present situation and to be able to appreciate the impact on the avifauna of major disturbances such as, in the case of Makatea, phosphate mining which drastically changed the vegetation of the island.

The following visits were used for our analysis:
- 1839: the United States Exploring Expedition, the 9th of September (PEALE 1848).
- 1899: Steamer "Albatross", the 26th of September and 6th of October (TOWNSEND and WETMORE 1919).
- 1901-02: A. Seale collected birds for the Bishop Museum (Honolulu), from the 29th of December 1901 to the 26th of January 1902 (SEALE MS).
- 1922: the Whitney South Sea Expedition (R.H. Beck and E. Quayle) collected birds for the American Museum of Natural History (New York), in August.

- 1929: the Crane Pacific Expedition during a brief stay (MAYR and CAMRAS 1932).
- 1932: the botanist Wilder mentions a rather complete list of birds (WILDER 1934).
- 1972: J.-C. Thibault stayed on December 18-19, in the village and in the inner forest.
- 1986-87: I. Guyot and J.-C. Thibault stayed from December 27, 1986 to January 4, 1987, visiting the northwest and northeast coasts, the area of the village Vaitepaua, as well as the area of Tahiva in the interior.

RESULTS

We present in chronological order data collected by the different visitors which are summarized in tables 1, 2 and 3.

- 1839: PEALE (1848) mentions only two species _Ducula pacifica aurorae_, qualified as "common", and _Vini peruviana_ which is only indicated, without further details, in the collected bird list.
- 1899: TOWNSEND and WETMORE (1919) give the first census of the avifauna, but _Vini peruviana_ is not mentioned. All other landbirds observed are qualified as "common".
- 1901-02: SEALE (MS) collected one specimen of _Vini peruviana_, confirming Peale's data. He notes in his journal that this species "is now quite scarce". All other species are considered as common, but _Ducula pacifica_ is found only "in the wilder parts". He proves the breeding of seabirds (the same species as nowadays).
- 1922: the Whitney South Sea Expedition collected all the earlier mentioned landbirds at the exception of _Vini peruviana_ which disappeared since the Seale's visit. All the birds are qualified as "common".
- 1929: the Crane Pacific Expedition collected only two species (MAYR and CAMRAS 1938) but did not bring any new information.
- 1932: WILDER (1934) mentions four breeding landbirds and four breeding seabirds.
- 1972: the only difference observed by Thibault with Seale's results 80 years before was the presence of the probably introduced _Lonchura castaneothorax_. Several tens of individuals were seen in the village gardens. _Ducula pacifica aurorae_ was common but confined to the inner forest. _Ptilinopus purpuratus chalcurus_ was frequent in all wooded habitats even in the village (one observation every 50th to 60th meters). _Acrocephalus caffer eremus_ was well distributed in all wooded habitats but less abundant in the inner forest.
- 1986-87: the introduced _Lonchura castaneothorax_ has disappeared. A new species _Zosterops lateralis_ was observed; it has probably colonized the island from Tahiti. This species is not abundant but is found isolated or in small

flocks in several places (village and inner forest). _Ducula pacifica aurorae_ is restricted to the inner forest. It was not observed in the vegetation recolonizing the former phosphate exploitation site. The inhabitants never observe it in or near the village. In the interior we could only go to Tahiva but the uniformity of the forest suggests that _D. p. aurorae_ lives from Aetia in the west to the southeast coast, which represents about one third of the island (see Fig. 1). In this area, the progression is made difficult by enormous blocks of coral (the "feo"). The birds are mainly recorded in small natural clearings. Transects made in the forest allowed us to count 10 to 15 individuals per kilometer. It is impossible to accurately evaluate the size of the population, but it can be estimated to be between 100 and 500 individuals. Situations of _P. p. chalcurus_ and _A. c. eremus_ are the same as in 1972. Finally _Gallus gallus_, not recorded before but probably introduced long ago, is regular in the village but absent elsewhere. In general, birds are not hunted anymore.

DISCUSSION

I. THE LANDBIRDS

Two forms are endemic : _Acrocephalus caffer eremus_ and _Ptilinopus purpuratus chalcurus_.

The absence of several species has to be noted, for example, _Porzana tabuensis_ which is known on neighboring atolls (Rangiroa, Tikehau: HOLYOAK and THIBAULT 1984, POULSEN and _al_. 1985). It is possible that the absence of wet areas in Makatea is the reason. _Gallicolumba erythroptera_ had formerly a vast distribution in the Society and Tuamotu archipelagos; PEALE (1848) found it on other islands of the Tuamotu but did not mention it for Makatea. _Aerodramus spp._, present in the Society and Marquesas Islands, could find many favorable breeding sites in the numerous cliff caves. _Halcyon gambieri_ is present on the nearby island of Niau where the forest shows a structure similar to one observed in Makatea.

In the XXth century, five native species were noted, from which one (_Vini peruviana_) disappeared between 1902 and 1922. This extinction is most probably related to a particularly violent hurricane or to the introduction of a predator (_e. g._ _Rattus sp._), than to the mining which was just starting at that time. During the same period two species appeared. _Lonchura castaneothorax_ (well established in the Society Islands) today extinct which was probably introduced from Tahiti at a time when Makatea had many residents and the exchanges between the two islands were frequent (1930-60); _Zosterops lateralis_ on the other hand has probably colonized Makatea on its own. The colonization

process of the Society Islands by this introduced species was completed in less than 30 years (HOLYOAK and THIBAULT 1984).

II. THE SEABIRDS

Only six seabirds breed on Makatea (table 2) and only little information was collected last century. Data collected between 1901-02 and 1987 show that there have not been any important changes. The data obtained in 1972 and 1986-87 underline the low number of Phaethon lepturus and Sula leucogaster, both being cliff breeders. Sula sula, Anous stolidus and Gygis alba have relatively high numbers. These three species find good breeding conditions in the large inner forest. In 1901-02, SEALE (MS) noticed that Sula sula was "largely used as food by the natives". Today, it appears that the situation has improved for nesting seabirds as this practise has ended.

The absence of breeders of some species, such as Sterna fuscata or Procelsterna cerulea, is puzzling. They may be conspicuous at other times of the year. It is also possible that a nocturnal Procellariiforme may breed in the cliffs, following the descriptions of the inhabitants who name such a bird "NOHA" (= Pterodroma rostrata in Tahiti).

III. THE CONSEQUENCES OF THE INDUSTRIAL PHOSPHATE MINING

The main changes that occured in Makatea since the last century are related to phosphate mining. The "Compagnie française des Phosphates de l'Océanie" founded in 1908 obtained the mining concession on the whole island in 1917. Mining stopped in 1964 following the exhaustion of the deposit which covered half of the island. The forest was destroyed and burnt to allow the phosphate extraction of a volume close to 11.2 millions tons (BOUZAT 1986). Mining left a vast excavation in the main deposit and also smaller holes, several meters deep, in the secondary deposit, which gave rise to a specially chaotic landscape.

Figure 1 shows that half of the island was drastically modified; no bird extinction seems to be the result of the mining. For two species (Ptilinopus p. chalcurus and Acrocephalus c. eremus), mining did not change the abundance and distribution. However, for Ducula p. aurorae, it seems to have reduced the forest area which covers nowadays less than a thousand hectares. On the other hand, it seems likely that it is because of the great difficulty to penetrate into the inner forest that its population was not exterminated through hunting, one of the rare hobbies of people employed by the company (700 in the 1960's).

IV. COMPARISON WITH THE SITUATION IN TAHITI

Ducula, Ptilinopus and Acrocephalus also breed in Tahiti

or are represented by local forms. In Tahiti, D. p. aurorae has become very rare and has not been observed with certainty since 1972 (HOLYOAK and THIBAULT 1984). Neither hunting, nor habitat destruction seems responsible for this situation. It was already rare towards the middle of last century (see PEALE 1848), a phenomenon which has been amplified since the introduction of a raptor (Circus approximans). Ptilinopus p. purpuratus is not rare in Tahiti, but is restricted to the densest vegetation. The introduction of Circus approximans seems also responsible for this situation. Today, Acrocephalus c. caffer has been limited to a particular type of vegetation such as bamboos, since the introduction of Acridotheres tristis. Before this introduction, it could be found in more types of habitats and was one of the commonest birds. For these forms, competition and predation by introduced species seem to have been the main causes of regression.

CONCLUSION

Island birds are "generalists" that develop life strategies that minimize extinction risks. One of the strategies consists in having a habitat use as diversified as possible (see LACK 1970, BLONDEL 1986 for examples). Most birds of Eastern Polynesia largely fit such a claim (insectivorous, HOLYOAK and THIBAULT 1977; frugivorous, HOLYOAK and THIBAULT 1978). Some are able to rapidly make profit from man-made modifications to habitats. They use cultures, gardens and secondary forests (e. g. Acrocephalus caffer, Ptilinopus dupetithouarsii in the Marquesas Islands).

Ducula pacifica aurorae also shows a generalist strategy, using dry forest on coral limestone (Makatea) and humid mountain forests (Tahiti). But it was unable to quickly colonize the parts of Makatea with modified vegetation while another frugivorous bird (Ptilinopus purpuratus) was able to do so. Since the end of the mining, over twenty years ago, D. p. aurorae has remained limited to a small part of the island, occupied by a fairly high density. Another pigeon, the Marquesas Pigeon (Ducula galeata) shows a similar behavior: since its discovery, in the years 1840 (BONAPARTE 1855), it has had the same distribution limited to a few valleys of one island only (Nuku Hiva), while other valleys also show habitats that seem suitable. The general distribution of these two species shows however that both of them lived on several islands, which suggests that there were enough exchanges between populations to avoid phenotypical differenciation despite important habitat differences. Ducula galeata for instance, probably lived on several islands of the Marquesas Islands in the past (HOLYOAK and THIBAULT 1984) and similarly D. p. aurorae

breeds on both Makatea and Tahiti and it is possible that this form, or a similar one, bred in the past on other islands (fossil records of Ducula cf. aurorae or Ducula cf. pacifica on Henderson Island, STEADMAN and OLSON 1985).

But the possibility that these pigeons were introduced on some islands by Polynesian people in the past must also be considered, these species having been formerly domesticated in Polynesia (see PEALE 1848 p.200, Lemaire and Schouten in O'REILLY 1963, THIBAULT 1986).

The behavior of these pigeons contrasts with the behavior of Ducula p. pacifica (Western Polynesia, Melanesia and Micronesia, MAYR 1945) which shows a high mobility in searching for food, using a wide range of habitats (dry and humid forests, plantations) and often crosses sea straits to travel from one island to another (MAYR 1945, WATLING 1982). At a short time scale, the pigeons of Eastern Polynesia show well "the fear of flying of island species" (DIAMOND 1981).

This incapacity to rapidly colonize new kinds of habitats for some polynesian birds has to be taken into account by conservation policies. It demonstrates the need to preserve habitats for species that may quickly become extinct because they are unable to adapt to rapid changes in their environment.

RESUME

L'avifaune nicheuse de Makatea est bien connue depuis le XIXème siècle. Plusieurs inventaires permettent de suivre les modifications intervenues dans sa composition. On relève ainsi la présence de cinq espèces terrestres (dont une éteinte) et de six oiseaux marins nicheurs. L'exploitation industrielle du phosphate, entre 1908 et 1964, a provoqué un changement considérable de la végétation de l'île, puisque plus de la moitié de sa superficie fut défrichée, mais elle n'a pas entraîné d'extinction d'oiseaux. Deux espèces (Ptilinopus purpuratus chalcurus et Acrocephalus caffer eremus) réoccupent avec succès les boisements secondaires qui recolonisent l'ancienne mine. Ce comportement a d'ailleurs été constaté dans d'autres îles de Polynésie où ces espèces exploitent largement les milieux anthropisés. En revanche, un carpophage (Ducula pacifica aurorae) a vu sa répartition se limiter à la partie de forêt laissée intacte, couvrant une superficie inférieure à un millier d'hectares. L'incapacité d'étendre rapidement sa "niche-habitat" le rend particulièrement vulnérable.

ABSTRACT

The avifauna of Makatea has been well-known since the XIXth century. Several inventories enable to follow modifications which occured in its composition. We notice five landbirds (one is now extinct) and six breeding seabirds. The industrial phosphate mining, between 1908 and 1964, has drastically changed the vegetation of the island, half the area of which has been destroyed. But it seems that this phenomenon has not provoked the extinction of birds. Two species (Ptilinopus purpuratus chalcurus and Acrocephalus caffer eremus) successfully occupy the secondary vegetation which colonizes the old mining area. A similar situation exists on other islands of Eastern Polynesia where these species or similar forms exploit largely man-made areas. On the other hand, the distribution of a pigeon (Ducula pacifica aurorae) has been reduced to the inner forest, not destroyed by the mining, which covers less than one thousand hectares. Its inability to rapidly extend its "habitat-niche" makes it very vulnerable.

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TABLE 1: NESTING LANDBIRDS OF MAKATEA ISLAND

	1839(1)	1899(2)	1902(3)	1922(4)	1929(5)	1932(6)	1972(7)	1986-87(7)
Egretta sacra		X	X	X		X	X	X
Ptilinopus purpuratus chalcurus		X	X	X	X	X	X	X
Ducula pacifica aurorae	X	X	X	X		X	X	X
Vini peruviana	X		X	!			!	!
Acrocephalus caffer eremus		X	X	X	X	X	X	X
Zosterops lateralis							-	X
Lonchura castaneothorax				-	-	-	X	-

Legend : X = present, ! = extinct, - = absent
(1) PEALE 1848, (2) TOWNSEND and WETMORE 1919, (3) SEALE MS, (4) Whitney Exp. in HOLYOAK and THIBAULT 1984, (5) MAYR and CAMRAS 1938, (6) WILDER 1934, (7) this work.

TABLE 2: NESTING SEABIRDS OF MAKATEA ISLAND

	1899(1)	1901-02(2)	1922(3)	1972(4)	1986-87(4)
Phaethon lepturus		N	N	N2	N2
Sula leucogaster			N	N2	N2
Sula sula		N	N	N3	N3
Anous stolidus	N	N	N	N3	N3
Anous tenuirostris		N	N	N	N2 (5)
Gygis alba		N	N	N4	N4

Legend : N = nesting, N2 = 10-99 pairs, N3 = 100-999 p., N4 = 1.000-9.999 p. (1) TOWNSEND and WETMORE 1919, (2) SEALE MS, (3) Whitney Exp. in HOLYOAK and THIBAULT 1984, (4) this work, (5) numerous non-breeding.

TABLE 3: LIST OF VISITORS ON MAKATEA ISLAND

	1899(1)	1901-02(2)	1922(3)	1932(4)	1972(5)	1986-87(5)
Fregata minor		P	P			P
Fregata ariel					P	P
Numenius tahitiensis	C			P		
Arenaria interpres				P		
Pluvialis fulva	C			P	P	P
Heteroscelus incanus		P	C	P	P	P
Sterna fuscata						P
Sterna bergii					P	P
Urodynamis taitensis		P	C	P		P

Legend : (1) TOWNSEND and WETMORE 1919, (2) SEALE MS, (3) Whitney Exp. in HOLYOAK and THIBAULT 1984, (4) WILDER 1934, (5) this work; C = collected, P = present

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NO. 301

LE ZOOPLANCTON DU LAGON DE CLIPPERTON

BY

J.-P. RENON

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SUMMARY

The Clipperton atoll (10°18'N, 109°13'W) is closed and holds a lagoon with marked stratification; surface waters are brackish (S=4/6%), but deep waters show a salinity close to that of seawater and high concentrations of H_2S; temperature and pH are high. In this paper, environmental data concerning the atoll, the lagoon and the surrounding ocean are recalled and are followed by the study of the zooplankton of the lagoon and ocean.

The lagoon plankton consists of only two species : the cosmopolite fresh- and brackish water copepod, Acanthocyclops robustus, and the circumtropical freshwater cladocera Latonopsis australis. In the surface layer, the abundance of lagoon plankton is high : the average value is of 7710 ind.m^{-3} and locally up to 16 000 ind.m^{-3} can be observed. The average biomass (dry weight) is of 83 mg.m^{-3}. The local distribution at the surface is heterogeneous : the abundance and biomass of organisms are less in the S.W. part of the lagoon by respectively a factor 10 and 4. Data from some vertical hauls (at 10 or 15 m depth) denote a lower abundance (five to tenfold) in depth than in the surface layer.

A demographic analysis of this community points out a clear dominance of the copepods over the cladocera, their numerical ratio being 2:1. The A. robustus population is three to sixfold more abundant in the surface layer than in vertical hauls ; it is mainly composed by mature adults of both sexes ; at the surface, the ratio of males to females ranged from a mean of 2 to 5% and in deep waters it is of 160%. Scarcity of juveniles and the simultaneous presence of ovigerous females shows that a new biological cycle begins this whole population in a homogeneous fashion. The L. australis population is mainly located in the surface layer, where it's concentration is 50 to 100 times higher than in vertical hauls. It is only composed of parthenogenetic females and juveniles of various sizes. The absence of males and of ephippial females indicates that the parthenogenetic phase continues.

The ocean plankton is constituted in its near totality by typical oceanic holoplankton ; copepods, chaetognaths and appendicularians make up more than 95% of the plankton and are identified specifically. The meroplankton accounts for an abnormally low proportion (about 1%) near an atoll.

The discussion focuses on the biological interest of lagoonar planktonic communities and the valuable ecological interest of this atoll in the perspective of atoll evolution. These two species keep a relation of predator (A. robustus) to prey (L. australis) and the absence of higher level predators grants a remarkable simplicity to the lagoon trophic network. A comparison with previous planktonic data shows that the evolution of this ecosystem is rapid : for the past twelve years, this fresh- and brackish water planktonic community has taken the place of a marine community. A surabundance of nutrients seems responsible for the evolution of this atoll.

LE ZOOPLANCTON DU LAGON DE CLIPPERTON

BY

J.-P. RENON*

INTRODUCTION

Les lagons d'atolls sont généralement occupés par de l'eau de mer ou une eau de composition chimique voisine de celle de l'eau de mer ; le zooplancton de ce genre de lagon a fait l'objet maintenant de plusieurs études (JOHNSON, 1954 ; TRANTER et GEORGE, 1972 ; MADHU PRATAP et al., 1977 ; RENON, 1977 ; GERBER, 1980, entre autres). Plus rares sont les lagons d'atolls contenant une eau de composition chimique fort éloignée de celle de l'eau de mer ; tout au plus dispose-t-on alors, dans quelques cas,de notes taxonomiques concernant les espèces planctoniques. Le lagon de l'atoll de Laysan, situé dans les îles Hawaii ou le lac Tegano dans l'île Rennell - un ancien atoll soulevé - situé dans les îles Salomon en sont des exemples ; dans le premier, l'eau du lagon est sursalée (CASPERS, 1968), dans le second elle est au contraire dessalée (WOLFF, 1970).

La présente étude concerne le zooplancton d'un lagon empli d'une eau dessalée et contenant en outre de l'hydrogène sulfureux : le lagon de l'atoll de Clipperton (Pacifique oriental). Les récoltes de plancton ont été réalisées lors d'une mission du bateau "La Calypso" du Commandant COUSTEAU, en mars 1980, et le Docteur TAXIT, participant de cette mission, a eu l'amabilité de nous en confier l'étude.

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I.- PRESENTATION DES LIEUX ET METHODES D'ETUDES

A.- Données générales

L'île de Clipperton (10° 18'N, 109° 13'W) se situe dans le Pacifique oriental, au large du Mexique. Elle est connu dans ses grandes lignes (SACHET, 1962 ; NIAUSSAT, 1978) et nous n'en rappellerons que quelques traits essentiels (Fig. 1). Cette île est un anneau corallien de faibles dimensions (environ 3 km de diamètre) qui comporte un rocher volcanique culminant à 29 m de hauteur. Il s'agit donc, selon la nomenclature récifale (BATTISTINI et al., 1975) d'un "presqu'atoll", bien que l'usage - que nous suivrons - ait consacré la dénomination d'atoll à son égard.

La ceinture corallienne totalement bouclée enferme un lagon qui se trouve ainsi isolé de l'océan voisin. Plusieurs zones récifales subaffleurantes encombrent ce lagon et l'une d'elles comporte une profonde dépression dénommée "trou sans fond" ; celui-ci atteint au moins 91 m, alors que dans le reste du lagon les profondeurs maximums varient selon les zones de 25 à 45 m.

En dehors de cette curiosité géomorphologique, trois traits généraux différencient très nettement ce lagon d'un lagon d'atoll classique: d'abord, l'absence totale de coraux vivants et, hormis quelques rencontres anecdotiques, des représentants habituels de la macrofaune benthique et nectonique ; ensuite, l'existence sur les fonds d'un important dépôt de vase ; enfin, la présence d'un herbier bien développé couvrant environ un quart de la surface du lagon.

B.- Données hydrologiques

1/ Le lagon (excepté le "trou sans fond")

Lors de la présente étude (mars 1980), TAXIT (1981) rapporte une température de l'eau du lagon d'environ 30°C et une salinité (teneur en Na Cl) croissant de 4 °/₀₀ en surface à 6 °/₀₀ à 12 m de profondeur. La valeur du pH en surface est élevée et comprise entre 8,78 et 9,19. Les teneurs en oxygène dissous sont en général faibles et nulles au-delà de 15 m de profondeur. La teneur en hydrogène sulfureux n'a pas été mesurée, mais la présence en profondeur en a été notée (NIAUSSAT, 1978). Ces données complètent celles rapportées par EHRHARDT (1986) en 1967-68; cet auteur observait à l'époque l'existence d'un gradient de salinité suivant la profondeur : les valeurs étaient de 4 à 5 % dans les 6 premiers mètres d'eau et atteignaient 13 à 21 % en profondeur.

2/ Le "trou sans fond"

Cette dépression présente des caractéristiques inhabituelles et, là encore, nous nous référerons aux données rapportées par TAXIT (1981). La température de l'eau est plus élevée d'environ 2°C au-delà de 30 m de profondeur que dans les couches supérieures. La salinité est de 4 à 5 °/₀₀ jusqu'à 7 m de profondeur, puis de 10 °/₀₀ à 10 m ; elle atteint

33,7 °/₀₀ et 34,5 °/₀₀ respectivement à 20 m et 34 m de profondeur. La teneur en hydrogène sulfureux est particulièrement élevée et elle atteint 100 mg/l au-delà de 15 m de profondeur. Des dépôts brunâtres de matière organique en voie de décomposition - présents çà et là aussi dans le reste du lagon - forment dans cette dépression un véritable bouchon localisé entre 30 et 40 m de profondeur. Enfin, la teneur de l'eau en certains éléments minéraux dissouts (magnésium, cuivre, fer, etc...) est bien supérieure à la moyenne océanique.

3/ L'océan

Autour de l'atoll, EHRHARDT (1976) relève en surface une salinité de 31,08 °/₀₀, et TAXIT (1981) de 34 °/₀₀. Cette dernière valeur est en accord avec les données mentionnées dans les manuels et, de ce fait, paraît plus vraisemblable. Selon MUROMTSEV (1958), la zone océanique entourant cet atoll est occupée en surface par un type d'eau qu'il dénomme "eau équatoriale de surface" (t° = 26 à 29°C ; S = 34 à 35 °/₀₀); l'aire occupée par ce type d'eau accuse un excès des précipitations (> 3000 mm par an) sur l'évaporation (1300 mm par an) particulièrement dans cette zone est du Pacifique. Selon des données plus récentes (REID, 1969 ; BEKLEMISHEV, 1971), la salinité moyenne des eaux de surface dans cette zone est de 33,5 °/₀₀. Dans la nomenclature de BEKLEMISHEV (1971), la zone océanique autour de l'atoll est occupée par "l'eau tropicale du Pacifique est" (équivalente en partie à "l'eau équatoriale de surface" de MUROMTSEV, précédemment cité) ; cette zone est dominée par l'important circuit rotationnel équatorial ("équatorial gyre") mis en évidence par cet auteur. Le mouvement général des eaux de surface baignant l'atoll participe du courant nord-équatorial et est dirigé vers l'ouest.

C.- Méthodes d'études

Des prélèvements de zooplancton ont été effectués dans le lagon et dans l'océan. Dans le lagon, 13 stations ont été repérées en vue d'une étude de répartition horizontale dans la couche de surface, et 3 stations pour explorer les couches sous-jacentes (Fig. 1). Les récoltes dans l'océan n'ont été effectuées qu'en surface, à titre comparatif.

Tous les prélèvements ont été effectués avec un filet conique de 50 cm de diamètre d'ouverture et de 45 µm de vide de maille. La station située dans le "trou sans fond" a été l'objet de 3 traines horizontales de surface et de 3 traits verticaux, dont 2 selon une distance connue. Dans le reste du lagon, on dispose de 12 récoltes provenant des traines horizontales de surface et de 2 récoltes issues des traits verticaux, selon des distances indéterminées.

Aucune mesure du volume d'eau filtrée lors des traits n'est disponible. Cependant, dans le lagon, la durée et les conditions de traine en surface sont tout à fait semblables et donc comparables. Selon TAXIT (1981), le volume d'eau filtré est estimé à 25 m^3 lors des traits dans le lagon, et à 50 m^3 dans l'océan.

Toutes les récoltes ont été réalisées de jour et le plancton

recueilli a été fixé dans une solution de formol et d'eau de mer. Tri et comptages ont été menés selon les techniques habituelles (sous-échantillonnage avec cylindre de FOLSOM et CUVETTE DE DOLLFUS) à partir de la fraction aliquote (1/5ème) qui nous a été confiée. Les résultats seront rapportés conventionnellement au mètre cube d'eau supposé filtré ; étant donné les conditions d'échantillonnage, cette référence volumétrique représente une valeur très approximative.

II.- RESULTATS

A.- Plancton du lagon

1/ Données taxonomiques et biogéographiques

Le plancton du lagon est composé essentiellement de deux espèces de crustacés qui sont les suivantes : un copépode cyclopoïde, Acanthocyclops robustus SARS, 1863 et un cladocère, Latonopsis australis SARS, 1888.

Il convient en outre de mentionner la présence dans quelques échantillons de plusieurs espèces benthiques : un copépode harpacticoïde diosaccidae, un isopode cirolanidae, un ostracode et un cladocère chydoridae du genre Alona. La présence de ces espèces benthiques récoltées à moins de dix exemplaires dans la totalité des échantillons de surface paraît accidentelle ; elles seront négligées dans la suite du texte et nous nous attacherons uniquement aux deux crustacés typiquement planctoniques.

a) Acanthocyclops robustus fait partie du groupe A. robustus - A. vernalis au sein duquel plusieurs types (ou formes ou sous-espèces, selon les auteurs) ont jadis été distingués. En raison de l'existence de nombreuses formes de transition, DUSSART (1969), se référant à PETKOVSKI (1954), ramène à trois types l'ensemble des formes du groupe : un type "vernalis", un type "vernalis setiger" et un type "robustus". Il maintient en outre les deux formes extrêmes que sont les types "vernalis" et "robustus" comme des espèces valides.

En raison de l'existence de formes transition entre ces deux espèces, quelques détails concernant celle rencontrée doivent être précisés. La formule des soies du troisième article de l'exopodite des pléopodes P1 à P4 est 3, 4, 4, 4, et ce caractère permet d'identifier assurément l'espèce A. robustus. En outre, le rapport du nombre de soies spiniformes au nombre de soies non spiniformes de l'article 3 de l'endopodite des pléopodes P1 à P4 est de 1/5, 1/5, 1/5 et 2/3. Nous sommes donc en présence du type "robustus" si l'on suit DUSSART (1969) ou du type "setosus" si l'on suit KIEFER (1976) ; ils correspondent tout à fait à ceux rencontrés en Finlande et décrits par FURASJOKI et VILJAMAA (1984).

A. robustus est une espèce cosmopolite des eaux douces et saumâtres (DUSSART, 1969). Selon MASTRANTUONO et STELLA (1974), elle est rencontrée en de nombreux endroits d'Europe, d'Asie, d'Afrique du Nord et d'Amérique centrale. Selon ces derniers auteurs, elle apparaît comme une

forme euryvalente, capable de vivre dans divers types d'eau et à diverses altitudes ; on la rencontre dans les mares, les marais, les étangs et les lacs, aussi bien dans les eaux douces que dans les eaux périodiquement ou constamment saumâtres.

b) Latonopsis australis. Les spécimens rencontrés dans ce lagon sont rattachés à l'espèce L. australis, en admettant avec HARDING et PETKOVSKI (1963) que plusieurs formes considérées antérieurement comme des espèces, dont la nord-américaine L. occidentalis BIRGE sont synonymes de L. australis. Le statut de cette espèce et de ses variantes étant encore un sujet d'études, nous nous référerons à la description faite par REY et VASQUEZ (1986) de spécimens du Vénézuéla, pour souligner quelques points de divergence ; pour le reste, nos spécimens s'accordent avec la description et les remarques de ces auteurs.

Les différences concernent l'antennule et l'antenne. La longue soie de l'antennule présente bien un aspect serraté, mais elle porte au moins vingt sétules. Si la basipode de l'antenne comporte à son extrémité deux tubercules doublement mamelonnés et une soie finement sétulée, l'épine distale ne paraît pas présenter de biseau à son extrémité. Le trait le plus important réside dans une certaine variabilité de l'antenne, puisque selon les individus, le premier segment de l'exopode porte cinq soies, comme ceux décrits par KOROVCHINSKI (in SMIRNOV et TIMMS, 1983) ou même six soies.

Cette espèce est surtout tropicale. En admettant la synonymie évoquée précédemment, elle se rencontre dans les trois Amériques, dans plusieurs îles d'Amérique centrale (COLLADO et al., 1984), en Europe, en U.R.S.S., en Chine, au Japon, en Afrique et en Australie. Elle paraît limitée aux eaux douces temporaires ou permanentes et ne semble pas avoir été rencontrée en eau saumâtre.

2/ Données quantitatives

a) Répartition en surface

Nous présenterons d'abord les résultats concernant la répartition des valeurs de biomasse et du nombre total d'individus par mètre cube d'eau, puis la répartition des deux espèces.

A partir des mesures établies par TAXIT (1981), l'ensemble des récoltes de surface aboutit à une biomasse moyenne (poids sec) de 83 ± 41 mg.m-3 ; les comptages que nous avons effectués sur ces récoltes de surface fournissent un nombre moyen de 7710 individus par m^3. La répartition des valeurs révèle une hétérogénéité faible. La tendance qui se manifeste est la suivante : la zone sud-ouest du lagon correspondant aux stations 1,2 et 5 présente une abondance planctonique plus faible que le reste du lagon ; 23,5 mg.m-3 contre 100,5 mg.m-3 et 855 ind.m-3 contre 9770 ind.m-3.

La répartition de chacune des deux espèces se présente ainsi : A. robustus est moins abondant dans la zone sud-ouest que dans le reste du lagon (483 ind.m-3 contre 5710 ind.m-3). L. australis, bien que pré-

sentant une variabilité d'abondance plus grande, suit le même schéma de répartition que A. robustus ; on trouve ainsi 370 ind.m-3 dans la zone sud-ouest et 4063 ind.m-3 dans le reste du lagon.

b) Répartition verticale

La répartition verticale n'a pas été étudiée directement ; cependant, la comparaison des récoltes issues des traits verticaux avec les récoltes de surface, dans la mesure où elle aboutit à des résultats très nets, permet de dégager les tendances de cette répartition. Deux prélèvements réalisés par trait vertical dans la zone du "trou sans fond" peuvent (seuls) être rapportés à un volume d'eau filtrée ; nous en comparerons les résultats avec ceux provenant des prélèvements de surface issus de cette même zone.

Ces résultats montrent que les rapports de densité planctonique provenant des deux types de récoltes sont nettement différents de l'unité et en faveur des récoltes de surface. Ces rapports sont les suivants: 5 à 10 pour le nombre total d'individus, 50 à 100 pour L. australis et 3 à 6 pour A. robustus. La densité de ces deux espèces, en particulier celle du cladocère, paraît ainsi plus élevée en surface que dans les couches sous-jacentes.

3/ Données démographiques

Nous analyserons la structure du peuplement planctonique en étudiant le rapport d'abondance des deux espèces, puis la composition de chacune des populations.

Le rapport de l'abondance d'A. robustus à celle de L. australis dans la couche de surface est égal à l'unité dans la zone centrale du lagon (stations 4,5 et 11) et dans la zone du "trou sans fond" ; dans le reste du lagon, ce rapport est de 2,2. Dans la couche d'eau explorée par les traits verticaux, ce rapport est de 14 dans le "trou sans fond" et de 1,3 à 7 aux deux autres stations offrant ce type de trait. On observe donc en général une nette prépondérance du copépode à raison en moyenne de plus de 2 copépodes pour 1 cladocère.

A. robustus est représenté dans les récoltes par des individus des deux sexes et accessoirement par de très rares copépodites, probablement au stade V. Dans la couche de surface, on récolte en moyenne 5 mâles pour 100 femelles ; ce pourcentage présente des caractères de grande constance et de faible variabilité puisque dans douze récoltes sur quinze, il est compris entre 0,9 % et 8,9 %. Dans la zone du "trou sans fond", on récolte en moyenne 2 mâles pour 100 femelles en surface, et 160 mâles pour 100 femelles dans la couche d'eau concernée par les traits verticaux. En outre, dans cette même zone, le rapport des densités rencontrées lors des traits de surface à celles rencontrées lors des traits verticaux est de 8 à 14 en ce qui concerne les femelles et de 0,1 à 0,25 en ce qui concerne les mâles. Autrement dit, les femelles de ce copépode semblent se concentrer en grand nombre en surface, alors que les mâles, avec des densités réduites, se situent plutôt dans les couches sous-jacentes.

L. australis est représenté dans les récoltes par des femelles parthénogénétiques et par des jeunes. En surface, les jeunes sont absents des zones du lagon bordant les rivages ouest, sud-ouest et sud-est (stations 1, 2, 3, 5 et 8). En outre, ces jeunes sont totalement absents des récoltes effectuées dans le "trou sans fond" - on les rencontre cependant ici en surface - et de l'un des deux traits verticaux réalisés ailleurs dans le lagon. Le dénombrement de ces jeunes reste incertain en raison de leur expulsion fréquente de la poche incubatrice des femelles qui les hébergeaient, sous l'effet de la fixation et des diverses manipulations.

B.- Plancton de l'océan

Le plancton de l'océan au voisinage immédiat de l'atoll est composé des représentants habituels des zones tropicales de surface. La liste des divers taxons et le pourcentage qu'ils constituent sont établis dans le tableau I. Les représentants de trois de ces taxons ont été identifiés à l'espèce en raison de leur abondance numérique et de leur intérêt écologique ; ce sont les copépodes, les chétognathes et les appendiculaires ; la liste en est dressée dans le tableau II.

Nous présenterons et discuterons succinctement les résultats de ces trois récoltes océaniques. Les copépodes sont numériquement prépondérants puisqu'ils constituent de 91,1 à 94,3 % du nombre total d'individus. Les familles prédominantes, citées en ordre décroissant d'importance, sont les suivantes : les pseudocalanidés et paracalanidés (40 à 52 %), avec comme espèces principales, Clausocalanus furcatus, Acrocalanus gracilis, Paracalanus aculeatus et Calocalanus pavo, les oncaeidés (15 à 25 %), les corycaeidés (6,6 à 11 %) avec principalement Farranula gibbula, les euchaetidés (3,2 à 8,3 %) et enfin les oithonidés (3,4 à 5,1 %).

A la suite des copépodes viennent les appendiculaires qui représentent 2,1 à 3,2 % du nombre total d'individus, puis les chétognathes (1,0 à 1,4 %), les siphonophores (0,8 à 1,6 %) et les salpes et dolioles (0,4 à 0,9 %). La totalité des taxons restant constitue moins de 2 % du nombre total d'individus dans chaque échantillon.

On remarque à quel point l'holoplancton est ici prépondérant, puisqu'il représente de 98,3 à 99,6 % du nombre total d'individus ; la composition spécifique des peuplements de copépodes, de chétognathes et d'appendiculaires atteste par ailleurs, de son caractère typiquement océanique. Or, on pourrait s'attendre à ce que l'influence de l'atoll se traduise en la rencontre d'une proportion importante de méroplancton issu d'adultes benthiques ou nectoniques habitant la pente externe ou les platiers extérieurs de l'atoll. Ici, il n'en est rien, et les courants contournant l'atoll par le nord et le sud (TAXIT, 1981) ne paraissent pas en cause, puisque les récoltes sont localisées à l'ouest et au sud-ouest de l'atoll, c'est-à-dire dans une zone où le méroplancton devrait précisément être entraîné et se trouver accumulé. Il faut donc souligner cette déficience méroplanctonique et en chercher une explication dans une faible abondance de géniteurs benthiques et nectoniques, ou bien dans les cycles de reproduction de ces géniteurs.

III.- DISCUSSION ET CONCLUSION

Nous discuterons d'abord des deux espèces planctoniques du lagon, puis de l'intérêt que présente ce milieu exceptionnel.

Les concentrations de plancton dans ce lagon sont très élevées ; elles dépassent localement 16 000 ind.m-3, c'est-à-dire qu'elles surpassent de plus d'un ordre de grandeur celles qu'on peut rencontrer dans les lagons d'eau de mer des atolls polynésiens (RENON, 1977) ; par contre, elles ne sont pas exceptionnelles dans les eaux continentales douces et stagnantes des tropiques (LEWIS, 1979).

Les concentrations les plus fortes concernent le cladocère et s'observent dans la couche de surface. Cette localisation pourrait n'être que passagère ; en effet, malgré l'absence de données comportementales concernant cette espèce, le phototropisme des cladocères est bien connu depuis les travaux de VIAUD (1938). De nombreuses études comme celles de LINCOLN (1970) ou de RINGELBERG (1964) ont montré que ces crustacés règlent leur position en profondeur selon l'intensité des diverses longueurs d'onde lumineuse pénétrant dans le milieu. C'est pourquoi la concentration rencontrée dans la couche de surface peut être éphémère et ne saurait être extrapolée à toute la masse d'eau ; ceci nous est confirmé par les traits verticaux qui révèle des concentrations 50 à 100 fois plus faibles.

La population de L. australis est constituée uniquement par des femelles et des jeunes de toutes tailles. L'absence de mâles et la présence de plusieurs embryons dans la poche incubatrice de ces femelles nous indiquent que cette population est en phase de reproduction parthénogénétique ; c'est d'ailleurs une règle générale chez les cladocères lorsque les conditions du milieu sont favorables (HEBERT, 1980).

Si l'absence des mâles pendant cette phase parthénogénétique n'est pas surprenante, elle amène néanmoins plusieurs remarques. D'abord, l'apparition des mâles s'effectuant peu avant l'avènement des femelles éphippiales qui engendrent des oeufs de durée, leur absence signifie que la phase éphippiale n'est pas proche. Ensuite, cette phase éphippiale survenant lorsque les conditions de milieu deviennent défavorables, l'absence des mâles indique que les conditions sont encore propices à la poursuite du développement parthénogénétique. Finalement, on peut se demander quelles sont les circonstances qui, dans ce milieu tropical, président à l'apparition de la phase éphippiale.

La population d'A. robustus est composée essentiellement d'adultes mâles et femelles. Nous avons vu que la proportion de femelles par rapport aux mâles est plus élevée en surface qu'en profondeur, ROMERO et BATTISTONI (1981) montrent que les mâles de cette espèce consomment moins d'oxygène que les femelles ; il est ainsi probable que dans ce milieu où les valeurs d'oxygène dissous sont faibles et nulles au-delà de 15 m de profondeur (TAXIT, 1981), les sexes se partagent l'épaisseur d'eau habitable selon le gradient décroissant d'oxygène depuis la surface jusqu'à tout au plus 15 m de profondeur.

L'absence totale de stades naupliens - le vide de maille du filet utilisé convenait à leur récolte -, la rareté des copépodites âgés et le pourcentage encore faible de femelles ovigères nous indiquent que cette population est en début de période de reproduction. Cette population composée d'individus ayant atteint le même stade de développement relève donc, selon toute vraisemblance, d'une seule et même dégénération. Là encore, quelles sont les circonstances qui synchronisent la reproduction des individus ou bien qui entraînent leur entrée en diapause, si elle existe ?

L'organisation trophique dans ce lagon paraît particulièrement simple et mériterait un intérêt soutenu ; en effet, un tel cladocère est classiquement herbivore ou détritivore et le copépode est un carnivore consommant de jeunes cladocères (BRANDL et FERNANDO, 1974). D'une part, on dispose donc d'un réseau trophique fort simple permettant d'étudier les relations d'un prédateur et de sa proie ; d'autre part, en raison de l'absence d'un prédateur de niveau supérieur, on a la chance de pouvoir tester facilement chez ce copépode certaines hypothèses, comme celle d'un sex-ratio égal à l'unité, en l'absence de pression de prédation (voir par exemple HAIRSTON et al., 1983). D'autres problèmes, tels ceux soulevés par LYNCH (1980) et liés au cycle biologique des cladocères, pourraient trouver une réponse dans ce lagon.

La composition de ce peuplement planctonique revêt un intérêt d'autant plus grand qu'elle peut être comparée avec les données rapportées par EHRHARDT (1976). Cet auteur rapporte l'existence dans le lagon, en 1968, de copépodes tachyidés, microsétellidés, oncaeidés, sapphirinidés et calanidés, ainsi que d'ostracodes, c'est-à-dire d'un certain nombre de familles exclusivement marines. Ainsi, sur la base de cet indice que constituent les copépodes, on constate qu'en douze ans, un zooplancton dulcaquicole ou saumâtre a remplacé un zooplancton marin au sein du lagon.

On peut d'ailleurs trouver un témoignage plus ancien de l'évolution faunistique de ce milieu ; en effet, M.H. SACHET (1962) mentionne l'absence de deux espèces jadis répertoriées dans le lagon : un isopode tanaïdacé et un décapode palaemonidé.

L'évolution de cet atoll et de son lagon pose enfin un problème majeur face à la théorie développée par ROUGERIE et WAUTHY (1986), basée sur le concept d'endo-upwelling. Selon ces auteurs, les écosystèmes récifo-lagonaires fonctionnent dans les déserts marins tropicaux grâce à une remontée d'eau océanique profonde riche en nutriants à travers la structure poreuse de l'atoll, sous l'action du flux géothermique. Les auteurs expliquent la mort de certains atolls par manque de nutriants, suite à une diminution du flux géothermique. A Clipperton, d'une part le socle volcanique émerge sous la forme d'un éperon rocheux situé dans la couronne corallienne et d'autre part un important peuplement aviaire déverse de grandes quantités de phosphates sous forme de guano. Les sels nutritifs et les éléments minéraux nécessaires à la production primaire tant lagonaire que récifale externe sont donc immédiatement disponibles sans l'intervention d'un moteur géothermique. Pourtant, depuis 1839, selon NIAUSSAT (1978), cet atoll jadis ouvert

sur l'océan s'est fermé, les madrépores et la faune récifo-lagonaires ont disparu, et le milieu intérieur marin est devenu saumâtre. A priori, l'évolution de cet atoll ne s'est donc pas opérée par faute de nutriants, mais au contraire par leur surabondance qui a entraîné probablement non seulement la fermeture, mais aussi, après dépôt de la matière organique élaborée, le colmatage de la trame poreuse qui assurait l'équilibre halin avec l'océan. Une étude sédimentologique devrait apporter la preuve de ce colmatage et révéler ainsi un processus pouvant entraîner la mort des atolls.

Clipperton a atteint un stade évolutif qu'on rencontre exceptionnellement sur le globe. Nous avons essayé de situer les données originales apportées par cet atoll dans le contexte de quelques problèmes actuels d'ordre biologique et écologique. Il offre l'opportunité de pouvoir fournir une réponse à ces problèmes. La communauté scientifique doit en être informée avant que des modifications majeures n'interviennent.

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Table I

Relative abundance of major taxa from oceanic surface layer Surrounding Clipperton atoll.

Copepods	91,06 - 94,27 %	Decapod larvae	0,07 - 0,11 %
Appendicularia	2,09 - 3,26 %	Gastropod larvae	0,07 - 1,07 %
Chaetognatha	1,04 - 1,36 %	Fish (eggs & larvae)	0,28 - 0,53 %
Siphonophora	0,77 - 1,57 %	Echinoderm larvae	0,00 - 0,11 %
Salps-Doliolids	0,38 - 0,91 %		
Pteropods	0,00 - 0,96 %		
Hyperiidea	0,08 - 0,55 %		
Euphausid larvae	0,05 - 0,26 %		
HOLOPLANKTON Total	98,32 - 99,59 %	MEROPLANKTON Total	0,41 - 1,68 %

Table II

Taxonomic list from dominant planktonic groups
in nearby ocean.

COPEPODA

- Calanoidea
  - Eucalanus attenuatus
  - Rhincalanus cornutus
  - Canthocalanus pauper
  - Undinula darwinii
  - Paracalanus aculeatus
  - Calocalanus plumosus
  - Calocalanus pavo
  - Clausocalanus furcatus
  - Clausocalanus arcuicornis
  - Acrocalanus gracilis
  - Acrocalanus gibber
  - Euchaeta marina
  - Euchaeta rimana
  - Centropages gracilis
  - Temora discaudata
  - Candacia truncata
  - Candacia pachydactyla
  - Candacia catula
  - Acartia negligens
  - Labidocera detruncata
  - Pontellina plumata

- Cyclopoidea
  - Corycaeus speciosus
  - Corycaeus robustus
  - Corycaeus pacificus
  - Corycaeus vitreus
  - Corycaeus crassiusculus
  - Farranula gibbula
  - Copilia mirabilis
  - Copilia quadrata
  - Sapphirina metallina
  - Sapphirina nigromaculata
  - Oithona setigera
  - Oncaea venusta

- Harpacticoidea
  - Macrosetella gracilis

CHAETOGNATHA

- Sagitta enflata
- Sagitta robusta
- Sagitta bedoti
- Sagitta pacifica
- Sagitta regularis
- Krohnitta pacifica
- Pterosagitta draco

APPENDICULARIA

- Oikopleura longicauda
- Oikopleura cophocerca
- Oikopleura fusiformis
- Megalocercus huxleyi
- Fritillaria borealis
  f. sargassi
  et F. intermedia

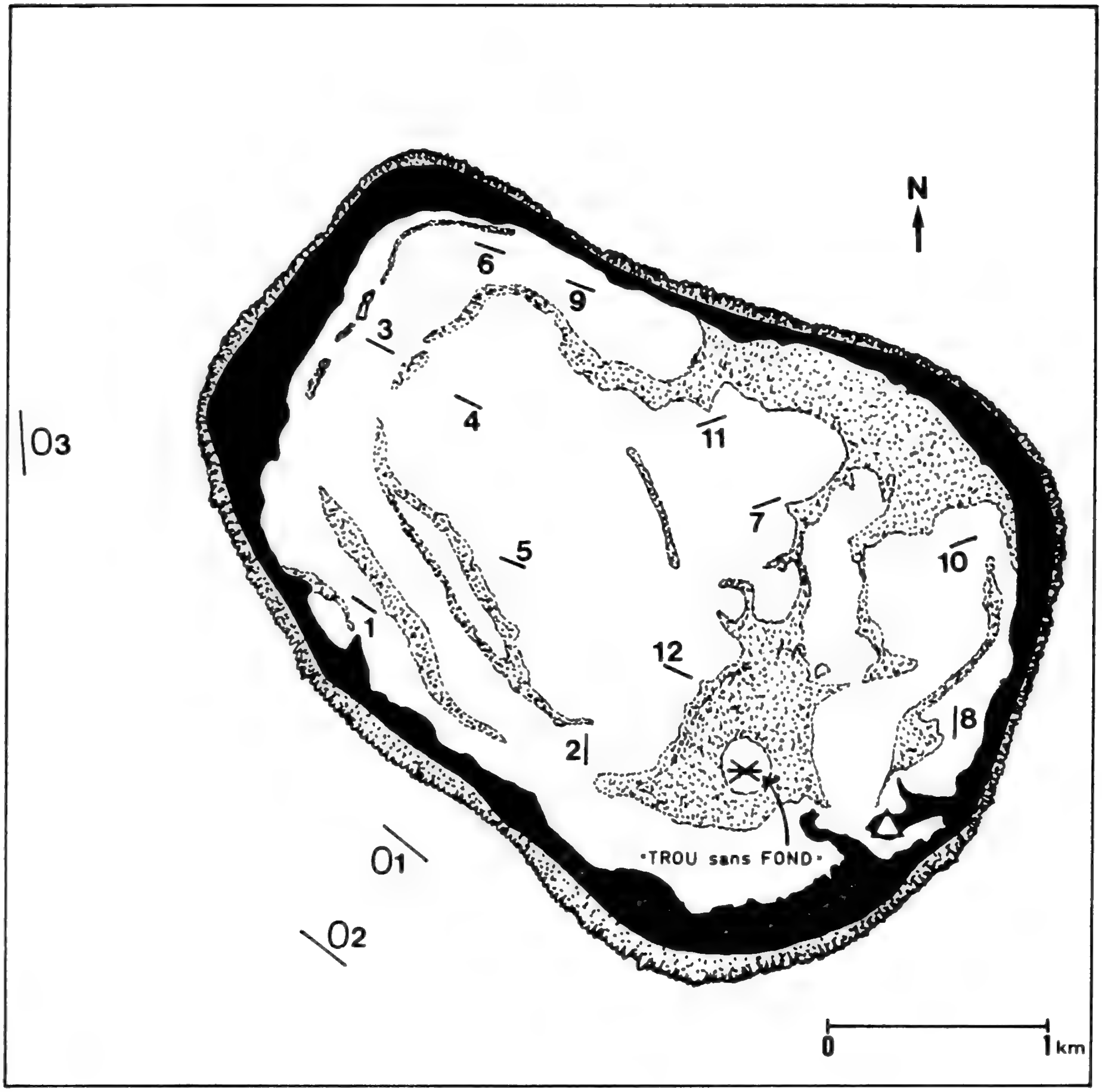

Fig. 1 - The Clipperton atoll and sampling stations.

emerged atoll rim ; △ Clipperton rock ;

dead drowned reef/outer reef-flat.

ATOLL RESEARCH BULLETIN

NO. 302

DOMINANT MACROPHYTE STANDING STOCKS, PRODUCTIVITY AND COMMUNITY STRUCTURE ON A BELIZEAN BARRIER REEF

BY

M. M. LITTLER, P. R. TAYLOR, D. S. LITTLER,

R. H. SIMS AND J. N. NORRIS

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BY

M. M. Littler*, P. R. Taylor**, D. S. Littler*,

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INTRODUCTION

Tropical reefs often consist of massive structures derived mainly from the fossil remains of coelenterate corals and calcareous algae. The biological communities responsible for such formations are noted for their diversity, complex structure and high primary productivity. Macroalgae play essential roles in the geology as well as the biology of reef complexes (e.g., James et al. 1976). The aragonite skeletal materials derived from calcareous green algae (Chlorophyta) and hard corals (Cnidaria) provide much of the structural bulk (James and Ginsburg 1979), while the calcite crusts produced by coralline algae (Rhodophyta) consolidate this material and other debris to augment reef formation. Additionally, the non-articulated coralline algae may form an intertidal algal ridge at the reef crest that buffers wave forces and prevents erosion and destruction of the more delicate corals and softer organisms typical of back-reef habitats. A diverse group of calcified green algae (Chlorophyta), belonging to the orders Caulerpales and Dasycladales, are the source of much of the sediment found throughout modern reefs.

One of the world's most extensive reef systems is the Belize Barrier Reef, 10 to 32 km wide and about 250-km long (James et al. 1976), the largest continuous reef in the Atlantic and the second largest in the world (Smith 1948). However, little quantitative information concerning the standing stocks, productivity, community structure and ecology of macrophytes is available for this impressive reef system. The few studies of plants to date include taxonomic collections taken along the shore or by dredging (e.g., Taylor 1935, den Hartog 1970, Tsuda and Dawes 1974). Norris and Bucher (1982) recently provided a floristic account of macrophytes near Carrie Bow Cay and vicinity. Several unique secondary metabolites have been revealed for Belizean macroalgae (e.g., McConnell and Fenical 1978,

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Gerwick and Fenical 1981, Norris and Fenical 1982, Paul and Fenical 1983, Gerwick et al. 1985). The important role of herbivory in structuring macrophyte communities has been thoroughly investigated for the Carrie Bow Cay reef and surrounding environs (Hay 1981a, Littler et al. 1983a, 1983b, Lewis 1985, 1986, Lewis and Wainwright 1985, Littler et al. 1986, 1987, Lewis et al. 1987, Macintyre et al. 1987). Quantitative studies concerning macrophyte abundances are limited to those within unidentified algal turfs (Dahl 1973, 1976) and on mangrove root and bank communities (Littler et al. 1985, Taylor et al. 1986). While Rützler and Macintyre (1982) established a permanent transect near Carrie Bow Cay that has been examined qualitatively by many zoologists over the past decade, no quantitative baseline assessment by plant specialists existed. Therefore, as a necessary first approach to the design of ecologically relevant experiments, we initiated a detailed survey of macrophyte distributions, abundances and productivities in the reef system seaward of Carrie Bow Cay.

STUDY AREA

This research was performed at the Smithsonian Institution's field station located on Carrie Bow Cay, Belize, Central America (16° 48'N, 88° 05'W; Fig. 1) during 11 to 15 April 1980. Carrie Bow Cay is one of several small islands composed of calcareous debris that has accumulated on the outer margin of the Belizean barrier-reef system. The island and its surrounding habitats comprise a well-developed biotic reef system removed from major anthropogenic influences. The topography, geology and general biology are well known due to nearly two decades of study (see Rützler and Macintyre 1982).

On the basis of dominant biological and geological characteristics, the barrier reef seaward of Carrie Bow Cay can be divided into four major habitat units: back reef, reef crest, inner fore reef and outer fore reef. Each unit, except for the reef crest, can be further subdivided into distinct zones (see Rützler and Macintyre 1982). Water movement and depth have been suggested (Rützler and Macintyre 1982) to be the main factors controlling these biological/geological zonation patterns. The back reef (0.1-1.0 m deep) is subjected to strong currents and the lagoonward transport of sediments. The water over the intertidal reef crest is in an almost constant state of agitation. The inner fore reef (1-12 m deep) is strongly affected by waves related to both normal trade wind conditions and storms. Conversely, the outer fore reef (> 12-m deep) is impacted only by long-period storm waves generated primarily by hurricanes.

METHODS AND MATERIALS

Standing Stocks

A single transect on compass heading 90° magnetic and 627-m in length was established seaward of the laboratory on Carrie Bow Cay (Figs. 1 and 2), beginning on the reef flat in 0.2 m of water and extending to a depth of 32.0 m. Depths shallower than 1.0 m were measured at the time of sampling with a meter stick, whereas deeper depths were read to an accuracy of 0.3 m using a Tekna expanded-scale depth gauge. Tidal amplitude is minimal relative to wave height at Carrie Bow Cay so average depths between wave peaks and troughs are given without reference to tidal stage. Quantitative samples were obtained on 11-15 April 1980 by photographing 1.0 m^2 quadrats at every third meter to meter 292, with the exception of meters 100-113 which were sampled at every meter due to rapid vegetational changes; every fifth meter was assessed from meters 292-627. Photographs were taken perpendicular to the substratum using a 35-mm Nikonos camera equipped with an electronic flash unit and Kodachrome-64 transparency film. Simultaneously, voucher specimens of all macrophytes and turf algae for taxonomic purposes were taken from each quadrat and placed in individually labelled bags. Vouchers were subsequently studied and deposited in the Algal Collection of the U.S. National Herbarium, National Museum of Natural History, Smithsonian Institution. The species and taxonomic authors are given in Table 1.

In the laboratory, the developed transparencies were projected onto a sheet (40 x 40 cm) of white paper containing a grid pattern of dots at 2.0-cm intervals on the side of the reflected light; this has been shown (Littler and Murray 1975) to be an appropriate density (i.e. 1.0 per cm^2) for consistently reproducible estimates of cover. The number of dots superimposed on each species was then scored twice (i.e. replicated after movement of the grid) with the percentage cover values expressed as the number of "hits" for each species divided by the total number of dots (~800) contained in the quadrats. Species present in vouchers but not abundant enough to be scored by the replicated grid of point intercepts were assigned a cover value of 0.1%. In cases of multi-layered communities, more than one photograph per quadrat was taken to quantify each stratum after upper strata had successively been moved aside.

The method as applied here does not allow for the quantification of microalgae (small epiphytic or endolithic forms) when they occur in low abundances. Our measurements were restricted to macrophytes that could be discerned in the field with the unaided eye. However, we did quantify small algae when they occurred in high abundances as components of algal turfs.

Table 1. Mean cover (±standard error) of the dominant macrophyte taxa in each zone indicated by cluster analysis.

Dominant Taxa								
Zones	1	2	3	4	5	6	7	
Distance from shore (m)	0-72	73-112	113-131	132-327	328-470	471-557	558-630	Means
Depth range (m)	0.2-0.4	0.1-0.8	0.1-0.9	2.5-8.8	7.9-15.2	23.2-29.0	16.5-31.1	
Mean depth (m)	0.3	0.3	0.6	5.8	10.3	25.1	24.6	
N =	24	22	7	61	28	18	14	
Amphiroa rigida var. *antillana* Boerg.	5.65 ±1.74							0.94
Amphiroa tribulus (Ell. et Sol.) Lamouroux				0.02 ±0.01	0.04 ±0.03			0.01
Amphiroa sp.				0.02 ±0.01	0.04 ±0.03	0.19 ±0.09	0.22 ±0.17	0.06
Anotrichium tenue (C. Ag.) Naegeli		0.64 ±0.26						0.11
Caulerpa racemosa (Forssk.) J. Ag.		0.66 ±0.32	0.06 ±0.05					0.12
Centroceras clavulatum (C. Ag.) Mount.		16.52 ±2.04		0.02 ±0.01				2.76
Ceramium nitens (C. Ag.) J. Ag.				0.04 ±0.01				0.01
Ceramium sp.		0.08 ±0.02						0.01
Champia parvula (C. Ag.) Harvey		0.04 ±0.01						0.01
Crustose coralline (unidentified)		16.77 ±2.83		0.01 ±0.01				2.80
Filamentous diatom		0.16 ±0.10						0.02
Dictyota bartayresii Lamouroux				0.32 ±0.01	1.84 ±0.30	1.38 ±1.21	1.65 ±0.61	0.64
Dictyota divaricata Lamouroux	0.13 ±0.09							0.02
Dictyota sp.		0.14 ±0.01						0.02
Galaxaura lapidenscens Lamouroux				0.17 ±0.04	0.01 ±0.03			0.02
Halimeda copiosa Goreau et Graham				0.16 ±0.04	0.20 ±0.08	0.17 ±0.16	2.36 ±1.24	0.45
Halimeda discoidea Decaisne				0.08 ±0.03	0.23 ±0.07	0.01 ±0.01	0.55 ±0.27	0.11
Halimeda goreauii Taylor					0.06 ±0.03	0.51 ±0.23	1.06 ±0.55	0.27
Halimeda opuntia (L.) Lamouroux	0.43 ±0.23	2.31 ±0.92	1.08 ±0.89	0.18 ±0.05	0.24 ±0.24			0.97
Hydrolithon boergesenii (Foslie) Foslie	0.19 ±0.08							0.03
Hypnea cervicornis J. Agardh			0.06 ±0.03					0.01
Jania adhaerens Lamouroux	0.15 ±0.08	2.64 ±1.07						0.46
Jania capillacea Harvey	0.11 ±0.11	1.94 ±0.74	1.38 ±0.89	<0.01 ±0.01				0.92
Jania rubens (Linneaus) Lamouroux		6.09 ±2.45						1.01

Laurencia obtusa (Huds.) Lamouroux		1.15 ±0.47						0.19
Laurencia papillosa (Forssk.) Grev.		0.72 ±0.72						0.12
Laurencia spp.		0.85 ±0.25	0.01 ±0.01	<0.01 ±0.01				0.14
Liagora spp.				0.47 ±0.28	0.32 ±0.22			0.07
Lobophora variegata (Lamour.) Womersley	0.05 ±0.05		0.59 ±0.38	0.01 ±0.01	0.25 ±0.07	0.74 ±0.57	3.84 ±1.43	0.88
Neogoniolithon strictum (Fosl.) Setch. et Mason	0.20 ±0.12							0.03
Neomeris annulata Dickie	0.02 ±0.01	0.03 ±0.01	0.01 ±0.01					0.02
Padina jamaicensis (Collins) Papenfuss		0.31 ±0.17						0.05
Penicillus dumetosus (Lamouroux) Blainville				0.05 ±0.02		<0.01 ±0.01		0.01
Peyssonnelia sp.	0.01 ±0.01	0.05 ±0.05	4.97 ±1.83					0.84
Polysiphonia howei Hollenberg		2.35 ±0.48						0.39
Porolithon pachydermum (Foslie) Foslie	1.20 ±0.50	1.55 ±2.80	26.91 ±8.97					4.94
Porolithon sp.	0.31 ±0.31	0.07 ±0.03	0.02 ±0.01					0.06
Rhipocephalus phoenix (Ell. et Sol.) Kuetz.				0.02 ±0.01	0.04 ±0.01	<0.01 ±0.01		0.01
Sargassum hystrix J. Ag.				0.07 ±0.02	0.11 ±0.05	0.02 ±0.02	0.42 ±0.15	0.09
Sphacelaria tribuloides Meneghini		0.85 ±0.33						0.14
Stypopodium zonale (Lamour.) Papenfuss				0.44 ±0.07	0.29 ±0.10	0.22 ±0.13	0.86 ±0.36	0.24
Taenioma nanum (Kuetz.) Papenfuss		0.34 ±0.07						0.06
Thalassia testudinum Banks ex Koenig	60.08 ±5.51							10.01
Trichogloeopsis cf. *pedicellata* (Howe) Abbott et Doty				0.28 ±0.07				0.05
Udotea cyathiformis Dec.				0.01 ±0.01	0.04 ±0.03	0.03 ±0.01	0.03 ±0.01	0.01
Wrangelia argus Montagne		0.44 ±0.40	4.30 ±2.79					0.79
Others (21)		0.27	0.01	0.32	0.16	0.14	0.01	
Total	68.53	56.97	39.40	2.71	3.87	3.43	11.00	30.91

Productivity

To compare the dominant macrophytes in terms of their functional-form groups (Littler 1980), and their net apparent photosynthetic performances, specimens were taken from the most abundant in situ populations along the transect line and allowed to acclimate in a running seawater system for one day. Four replicate incubations per species were conducted in a shallow current channel at ambient water temperatures (27°C) on 12 April 1980 between 0900 and 1430 hrs, under a photon flux of 900 to 2100 micro Einsteins $\cdot$ m^{-2} $\cdot$ sec^{-1} of photosynthetically active radiation. This was within the range of light saturation values documented for other macroalgal species (King and Schramm 1976; Arnold and Murray 1980; Lapointe et al. 1984). Net productivity was measured to 0.1 parts per million of dissolved oxygen by means of a YSI Model 57 oxygen analyzer and calculated as milligrams carbon fixed per unit of thallus weight per hour assuming a photosynthetic quotient of 1.00. The methods concerning the selection of material, handling, incubation and oxygen analysis were within the limits recommended by Littler and Arnold (1985).

Analyses of Data

Data obtained by photogrammetric sampling (Littler and Littler 1985) enable quantification of the distributions and abundances of standing stocks in relation to transect distances and depths. To characterize natural species assemblages over the entire length of the transect in an unbiased manner, the cover data of every species for all quadrats (except those with only bare sand) were subjected to hierarchical cluster analyses (flexible sorting, unweighted pair-group method; Smith 1976) using the Bray and Curtis (1957) coefficient of similarity. Due to the patchy nature of the biota, quadrat groupings by this technique reveal only trends and not statistically clear-cut assemblages. The resultant dendrogram of quadrat groupings was interpreted according to the dominant biota and environmental affinities and used to map the prevalent zonational patterns. All quadrat data within the clustered zones were summed and averaged to yield mean cover values that enabled us to interpret differences in macrophyte populations and communities between habitats.

Diversity measurements have been widely employed by those responsible for assessing the effects of disturbances on biotic communities. Species diversity is often measured by indices (see Poole 1974 or Pielou 1975 for references and definitions) that include components of both species richness and equitability (the evenness with which the individuals are apportioned

among species). The problem with any single index is that both the richness and equitability components of diversity are obscured. Many diversity indices also contain the underlying assumption that the ecological importance of a given species is proportional to its abundance. We have attempted to avoid these problems by using the commonly-applied Shannon and Weaver (1949) H' index (incorporating both richness and evenness) along with separate indices for richness (counts of taxa) and equitability (E'; Buzas and Gibson, 1969). These were calculated for the mean cover data by zone using natural logarithms and provided supplementary between-habitat comparisons of community structure.

RESULTS

Standing Stocks

The cluster analysis revealed seven general zones in the reef system off Carrie Bow Cay (Fig. 3) grouped as a function of both distance and depth. Because of the patchy distribution and low abundances of some organisms and sand, several quadrats are clustered with samples outside their habitat groups. A total of 70 macrophyte taxa occurred in the photographic samples (Table 1) with the majority present in zones 2 and 6 and the least number in zone 3 (Table 2). Zone 1, between 0 and 72 meters from the shoreline and extending over a depth range from 0.2 to 0.5 m (mean = 0.3 m) on the shallow reef flat (a portion of the back-reef region, Fig. 3), included a discrete grouping of quadrats with a high level of similarity. Total plant cover averaged 68.5% and the seagrass Thalassia testudinum was dominant (average cover of 60% with maxima to >100%, Figs. 4 and 5). Other major species of zone 1 were the articulated coralline Amphiroa rigida var. antillana, which occurred predominantly on the shoreward half of the zone (mean cover of 5.6%), and the crustose coralline Porolithon pachydermum (1.2% mean cover) growing mainly on the exposed skeletons of dead and living Porites porites (Pallas) primarily toward the seaward portion of the zone.

Zone 2, between meters 73-111 (depth range 0.1-0.8 m, mean = 0.3 m), included the rubble-pavement current channel of the back reef and inner slope of the reef crest (see Rützler and Macintyre 1982) and was dominated by crustose corallines overgrown by microfilamentous algae (Figs. 4 and 6). Total plant cover averaged 66.8% with the primary taxa being an unidentified crustose coralline (16.8%) and the filamentous red alga Centroceras clavulatum (16.5%), which together with other filamentous species such as Polysiphonia howei (2.4%) formed a turf-like mat. Also abundant in zone 2 (Fig. 4) were Porolithon pachydermum (11.6%), the turf-forming articulated corallines Jania rubens (6.1%), J. adhaerens (2.6%) and J. capillacea (1.9%). The articulated, calcareous green alga Halimeda opuntia (2.3%) and the coarsely branched red alga Laurencia obtusa (1.2%) also were conspicuous in patches on the shallow inner slope of the reef crest area.

Table 2. Measures of diversity within the six cluster zones.

	Zones							
	1	2	3	4	5	6	7	
Distance from shore (m)	0-72	73-112	113-130	131-327	328-470	471-555	556-630	Entire Transect
Shannon-Weaver Diversity (H')	1.64	2.52	1.89	2.35	2.38	1.63	0.29	3.32
Equitability (E')	0.37	1.43	0.55	0.47	0.57	0.01	0.06	0.41
Number of Species in Photo-samples	11	18	13	33	27	15	12	64

Zone 3 comprised a narrow biological habitat (meters 112-130, depth range 0.1-0.9 m, mean = 0.5 m) on the uppermost portion of the intertidal reef crest (Fig. 2) and had a total plant cover of 49.4%. This portion of the reef was dominated by a pink pavement of Porolithon pachydermum (34.6% mean cover, maxima to 80%, Figs. 4 and 7) containing excavations made by the chiton Acanthochitona lata Pillsbury (J. Houbrick personal communication; Fig. 8). Other prevalent species (Table 1) on the seaward crest were the encrusting red alga Peyssonnelia sp. (6.4%), turf-forming Wrangelia argus (5.5%) and Jania capillacea (1.8%). Beneath ledges and deep in crevices beyond the range of our photo-samples, the encrusting form of the green alga Codium intertextum predominated on the outer margin of the zone 3 reef crest.

Contrasting with zones 1-3, the remaining 4 zones occurred over regions with indistinct physical environmental boundaries and were biotically much less discrete (Fig. 3). For example, zone 4 was a broad region extending from meters 131-170 (depth range 1.5-4.6 m, mean = 3.6 m) that contained quadrats with relatively low algal abundances which showed low levels of floristic similarity (Fig. 3). This region corresponded to the upper fore-reef slope habitat (i.e., the high spur and groove system of Rützler and Macintyre 1982). Total plant coverage in zone 4 averaged only 4.5% (Table 1), dominated by Porolithon sp. (2.6%) and Halimeda opuntia (1.2%) along with sparsely scattered thalli of various coarsely branched algal forms (Figs. 4 and 9).

Zone 5 (meters 171-322, depth range 4.9-8.8 m, mean = 7.3 m) included most of the lower spur and groove habitat on the lower fore reef described by Rützler and Macintyre (1982), which had extremely low macrophyte cover (mean of 2.5%) composed of epilithic forms on reef rock and scattered rubble. The dominant species were the sheet-like Stypopodium zonale (0.6% cover) and Dictyota bartayresii (0.4%, Figs. 4 and 10).

The lower, fore-reef, sand-channel habitat characterized zone 6 (Fig. 3), which extended from meters 323-547 over a broad depth range of 7.9-29.0 m (mean = 13.5 m). Cover was sparse (3.4%), consisting mainly of epilithic forms on scattered rubble or psammophytic, rhizoidal, green-algal species embedded in sand. Dictyota bartayresii (1.6% cover) was most abundant (Fig. 4) followed by Lobophora variegata (0.2%), Stypopodium zonale (0.2%) and Halimeda goreauii (0.2%).

As in the cases of zones 4, 5 and 6, zone 7 also was characterized by a diffuse assemblage of relatively loosely clustered quadrats (Fig. 3). The zone included the outer reef ridge from meters 548-630 (depth range from 16.5-32.0 m, mean = 24.5 m) extending well beyond our maximum depth of 35 m. Algal cover averaged 10.3% (Figs. 4 and 11), composed mostly of the shelf-like form of the brown alga Lobophora variegata (3.7%), Halimeda copiosa (2.0%), Dictyota bartayresii (1.4%), H. goreauii (1.2%) and Stypopodium zonale (0.8%).

Table 3. Productivity (as mg C fixed per unit of thallus weight per hour at 1500 µE $m^{-2} \cdot s^{-1}$) of the dominant taxa found on the Carrie Bow Cay transect. (± 1 Standard Deviation)

Species	Productivity Dry weight (g)	Organic weight (g)	% Organic
Sheet group			
Dictyota divaricata	4.52 ±0.31	9.64 ±0.71	47.04 ±3.97
Dictyota bartayresii (turf-form)	1.20 ±0.21	2.91 ±0.58	41.84 ±6.66
Mean	2.86	6.28	44.44
Filamentous group			
Centroceras clavulatum (turf-form)	0.54 ±0.05	1.48 ±0.24	23.13 ±2.63
Caulerpa verticillata (turf-form)	0.66 ±0.17	1.86 ±0.40	21.13 ±0.78
Mean	0.60	1.67	22.13
Coarsely branched group			
Trichogloeopsis cf. pedicellata	2.39 ±0.39	10.14 ±0.35	25.65 ±3.86
Liagora farinosa	1.59 ±0.67	10.01 ±2.58	15.40 ±3.34
Liagora sp. #2	0.76 ±0.13	8.04 ±1.24	9.37 ±0.29
Laurencia obtusa	3.41 ±0.51	7.99 ±0.96	42.61 ±1.87
Liagora sp. #3	0.73 ±0.06	7.15 ±0.79	10.27 ±0.72
Gelidium sp.	3.21 ±1.33	5.92 ±2.26	54.31 ±5.08
Liagora pinnata	0.99 ±0.18	4.59 ±0.75	21.54 ±0.73
Rhipocephalus phoenix	0.79 ±0.34	4.59 ±1.19	17.15 ±4.30
Laurencia papillosa	1.39 ±0.13	3.71 ±0.42	37.45 ±2.54
Udotea cyathiformis	0.55 ±0.31	3.15 ±0.88	16.83 ±5.04
Neomeris annulata	0.39 ±0.07	2.37 ±0.37	16.29 ±0.60
Penicillus pyriformis	0.37 ±0.07	2.70 ±0.92	14.21 ±3.18
Caulerpa racemosa	0.45 ±0.18	0.88 ±0.36	51.07 ±0.78
Mean	1.31	5.48	25.54
Thick leathery/rubbery group			
Sargassum hystrix	2.14 ±0.06	3.63 ±0.17	59.06 ±2.98
Stypopodium zonale	1.55 ±0.33	2.97 ±0.59	52.30 ±7.29
Lobophora variegata	1.52 ±0.41	2.53 ±0.46	59.70 ±9.71
Thalassia testudinum	0.85 ±0.05	1.41 ±0.13	60.10 ±4.44
Padina jamaicensis	0.66 ±0.06	1.21 ±0.12	55.37 ±7.01
Mean	1.35	2.35	57.34
Jointed calcareous group			
Jania adhaerens	0.25 ±0.02	2.06 ±0.21	12.34 ±0.67
Halimeda opuntia	0.21 ±0.12	1.94 ±0.98	10.06 ±1.92
Amphiroa rigida var. antillana	0.11 ±0.01	0.98 ±0.11	11.36 ±0.13
Halimeda discoidea	0.21 ±0.07	0.96 ±0.33	21.97 ±0.41
Halimeda goreauii	0.04 ±0.01	0.77 ±0.19	5.27 ±0.25
Halimeda copiosa	0.05 ±0.02	0.95 ±0.52	12.43 ±0.86
Mean	0.14	1.27	12.24
Crustose group			
Neogoniolithon strictum	0.06 ±0.004	0.32 ±0.06	17.39 ±2.56
Peyssonnelia sp.	0.01 ±0.001	0.12 ±0.01	6.21 ±0.22
Hydrolithon boergesenii	0.01 ±0.001	0.11 ±0.01	6.21 ±0.99
Porolithon pachydermum	0.01 ±0.003	0.09 ±0.02	10.75 ±1.24
Mean	0.03	0.16	10.14

Community Diversity

Overall Shannon-Weaver (H') diversity was 3.35 and equitability (E') was 0.40. Zone 2, the narrow inner reef crest and pavement region, was by far the habitat of greatest diversity (Table 2); although comprising only 6% of the total area studied, it contained 42% of the total species encountered, a Shannon-Weaver (H') diversity of 2.59 and E' of 0.44. Zones 1 and 3 were dominated by extensive cover of relatively few species (Tables 1 and 2), and, along with zone 7, contained the fewest species numbers. Equitability values were especially low for the fore-reef zones 4, 5 and 6 (Table 2).

Productivity

Members of the sheet group had the greatest mean net photosynthetic rate in terms of thallus organic content (Table 3), with 6.28 mg C fixed · g organic dry $wt^{-1} \cdot h^{-1}$, and the crustose group the lowest with 0.16. The mean for the coarsely branched group was surprisingly high (5.48 mg C fixed · g organic dry $wt^{-1} \cdot h^{-1}$), whereas the turf-forming filamentous forms showed relatively low rates (mean of 1.67). The sheet-like Dictyota divaricata (4.52 mg C fixed · g total dry $wt^{-1} \cdot h^{-1}$) showed the highest rate on a total dry weight basis, followed by the coarsely branched Laurencia obtusa (3.41) and Gelidium sp. (3.21) along with the thick leathery species Sargassum hystrix (2.14). The crustose and calcified species were by far the lowest producers (Table 3). The turf forms, such as D. bartayresii, Centroceras clavulatum and Caulerpa verticillata contained tightly bound inorganic and organic sediments in their mats and were incubated in this natural condition.

DISCUSSION

This paper presents the first quantitative description of the macrophyte zonational patterns and primary productivity of dominant plant-life for the seaward margin of the Belize Barrier Reef. The zonational patterns, with minor exceptions, correlate well with the physiographic regions determined by Rützler and Macintyre (1982) along a parallel transect to the north. The community composition and zonation of the Carrie Bow Cay portion of the Belizean barrier reef, despite some variation (Burke 1982), is thought to be representative of the entire reef platform. Distinct similarities exist between the Belizean barrier reef's biological/geological zonation and the barrier reefs of the north coast of Jamaica (Goreau 1959, Goreau and Land 1974). Also bearing close similarities to the system we studied are the high relief spurs and ridges on Haiti's north coast and off southeast Alarcran (Burke 1982). Some portions of the Belizean barrier reef contain large standing

stocks of Turbinaria spp. and Sargassum spp. leeward of the back-reef rubble and pavement zone [e.g., the leeward sediment apron of Tobacco Reef (Macintyre et al. 1987)], whereas other regions (Burke 1982) appear to be more similar to the system we measured.

Halimeda has been documented (James and Ginsburg 1979, Rützler and Macintyre 1982) as a major sediment producer on Belizean reefs, extending from the shallow lagoon to its living depth range of 100 m. Four species of Halimeda covered an average of 1.3% of the total area transected, which indicates the considerable abundance of this genus throughout the reef system. Articulated corallines averaged 2.7% cover and crustose corallines totaled 9.6% mean cover, further substantiating the dominance of calcifying algae at Carrie Bow Cay, a phenomenon also noted (e.g., Littler 1976, Connor and Adey 1977, Wanders 1977) for other reef systems exposed to high grazing pressures.

The upper and lower spur and groove system (zones 4 and 5 and sand channel zone 6) had very low equitability values (Table 2) due to the clumped distribution of algae near relatively unpalatable larger plants and animals. Littler et al. (1986, 1987) have explored this phenomenon in some detail for the Carrie Bow Cay fore-reef system and experimentally documented refuges from fish predation afforded a group of 11 marine algae by the purple sea fan, Gorgonia ventalina Linnaeus, the fire coral, Millepora alcicornis Lamarck and the herbivore-resistant brown alga, Stypopodium zonale.

Productivity values for the six habitats indicated by the cluster analysis could not be calculated because of the large environmental differences involved (e.g., depth, light quality and quantity, etc.) and the fact that all incubations were done under uniform conditions. However, because of considerably higher algal cover, greater light energy and a preponderance of the more productive macrophytes, the shallower zones 1, 2 and 3 would be expected to contribute considerably more per unit area to overall reef productivity than zones 4-7.

Previous studies (Littler 1980, Littler et al. 1983a) have shown a strong correlation between algal functional-form groups and net photosynthesis, with sheet-like and filamentous forms producing at the highest rates. In contrast, our data showed extremely low rates for Dictyota bartayresii, a sheet form with unusual natural products (Norris and Fenical 1982), and both of the filamentous species (Centroceras clavulatum and Caulerpa verticillata). All of these occurred predominantly as tightly clumped

mat-like turfs containing particulate matter, which lowered their weight-based productivity. Also, such a compact configuration results in intraspecific competition for light, nutrients and gas exchange, which greatly limits the photosynthetic capacity of potentially productive forms. Conversely, the lightly calcified nemalian algae Trichogloeopsis pedicellata, Liagora farinosa and Liagora sp.(#2) had very high rates based on their organic contents. These forms appear to be annuals that reach their maxima in the spring. As has been noted often (e.g., Marsh 1976, Littler 1980, Littler et al. 1983a, Littler and Littler 1984), the heavily calcified crustose algae, such as Hydrolithon boergesenii, Porolithon pachydermum and Neogoniolithon strictum, show dramatically lower production rates, whether calculated on the basis of total dry weight or organic weight.

Herbivory, due primarily to grazing fishes, appears to be one of the most important causal agents determining the zonational patterns we observed. Rützler and Macintyre (1982) and Burke (1982) suggest that the direction and force of water motion controls the zonation of the Belizean Barrier reef biota, particularly corals (Geister 1977). However, Carrie Bow Cay and its surrounding habitats have been sufficiently studied in regard to the role of fishes and sea urchins to enable strong correlations and predictions to be made concerning the relative dominance of fleshy vs. calcareous macrophytes and the intensity of fish grazing (Hay 1981a, Littler et al. 1983a, 1983b, 1986, 1987, Lewis 1985, 1986, Lewis and Wainwright 1985, Taylor et al. 1986, Lewis et al. 1987, Macintyre et al. 1987). Assays of grazing intensity (Hay 1981a, Lewis and Wainwright 1985) and fish abundances (Lewis and Wainwright 1985) showed the following ranking from areas of lowest to highest herbivore activity: the Thalassia-area (zone 1), the lower fore reef (zones 5 and 6), the outer ridge (zone 7), the upper fore reef (zone 4) and the rubble and pavement portion of the back reef (zone 2). Because large fishes can not gain access to the shallow reef flat (zone 1), Thalassia testudinum becomes dominant in this sedimentary environment. Even during exceptionally high tides, the lack of protective cover would make fish vulnerable to the predatory osprey, Pandion baliaetus (Linnaeus), which we have observed frequently (i.e., usually twice daily) foraging on the shallow reef flat, and often landing with fish prey in the palm trees of Carrie Bow Cay. Also, the intertidal reef crest (zone 3) is too shallow for foraging fishes, enabling desiccation-resistant turf formers (Dawes et al. 1978, Hay 1981b) to persist on the less turbulent landward margin. However, the seaward portion of the reef crest gets buffeted by the shearing forces of occasional storm waves (Macintyre et al. 1987) that may tend to periodically eliminate much of the relatively delicate filamentous turf algae. The seaward crest also contains an abundance of the physically resistant, crustose coralline Porolithon pachydermum that appears to be maintained free of competitively superior epiphytes (Littler and Doty 1975, Wanders 1977) by its association with an undescribed grazing chiton (Fig. 8).

In the eastern Caribbean reefs of lower islands, where the force of water movement across intertidal ridges prevents intense grazing by fishes and echinoids, higher levels of algal standing stocks and productivity develop; on the eastern higher islands, where wave action is great, dense standing stocks of larger fleshy algae can extend to depths of at least 10 m (Connor and Adey 1977). Abiotic factors are also important in affecting the abundances and seasonality of algae on plant-dominated, fringing reefs, such as in Caribbean Panama (Kilar et al. in press). In agreement, the standing stocks of the intertidal reef crest at Carrie Bow Cay appear to be largely influenced by wave force and aerial exposure. Conversely, the macrophyte communities of the shallow subtidal zones are largely governed by fish herbivory. Thus, the relative importances of abiotic and biotic factors on algal standing stocks and productivity vary considerably throughout the different zones of this Belizean reef system.

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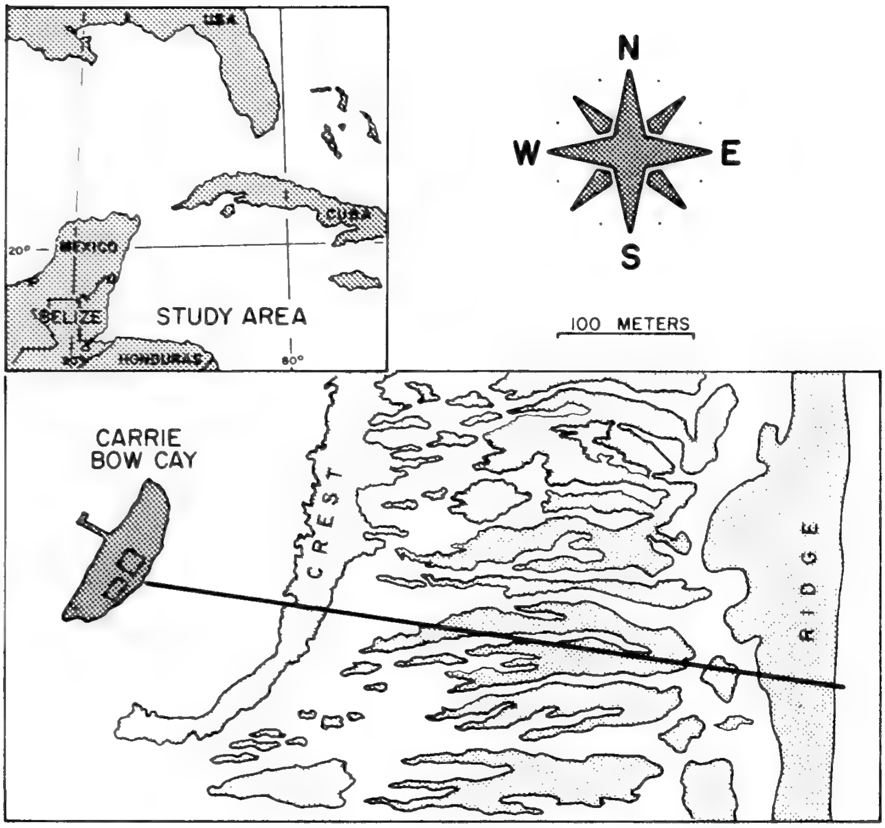

Figure 1. Location of study area and transect (90^{0} magnetic) in relation to the major topographic features of Carrie Bow Cay.

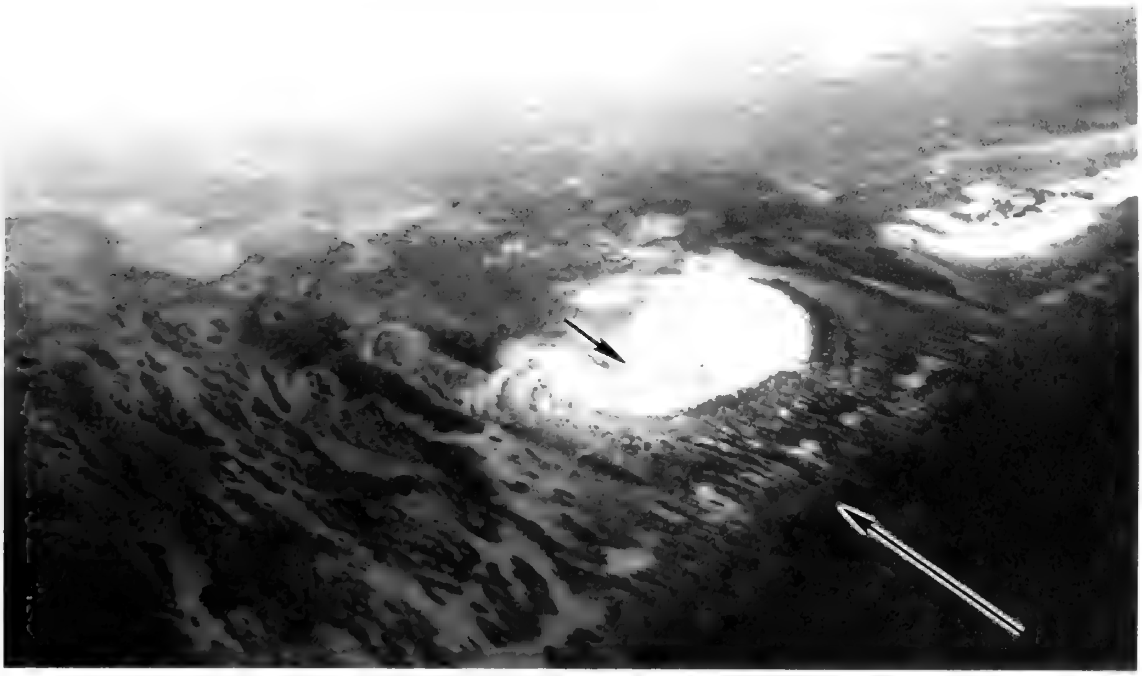

Figure 2. Oblique aerial view of Carrie Bow Cay and surrounding reef systems showing the area transected (between the two arrows).

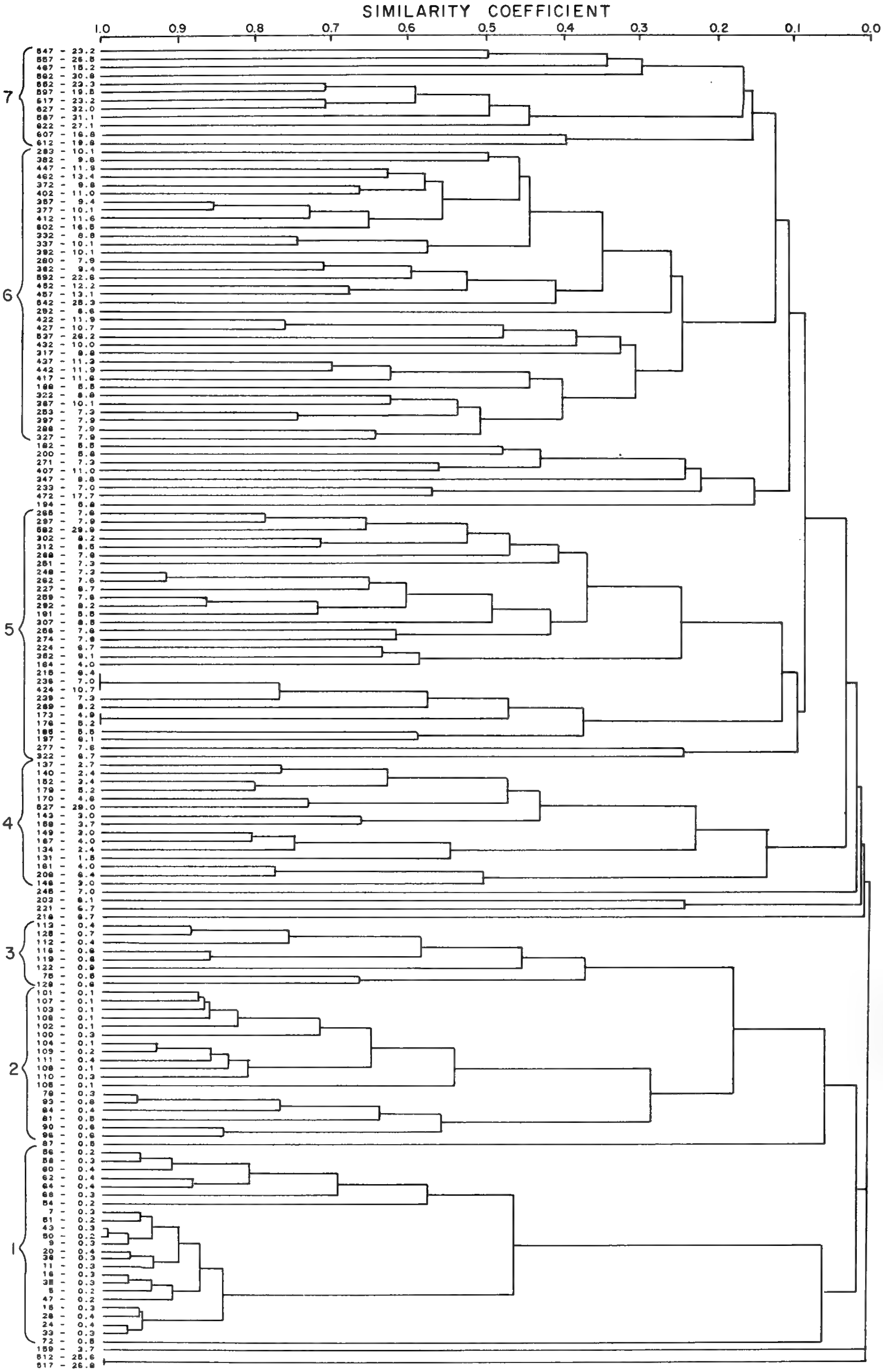

Figure 3. Dendrogram display based on differential clustering analysis of the percentage cover data of macroalgal species for all quadrats (labelled by depth and distance from shore in meters). The seven major zonal areas are indicated. Samples with no algae have been eliminated.

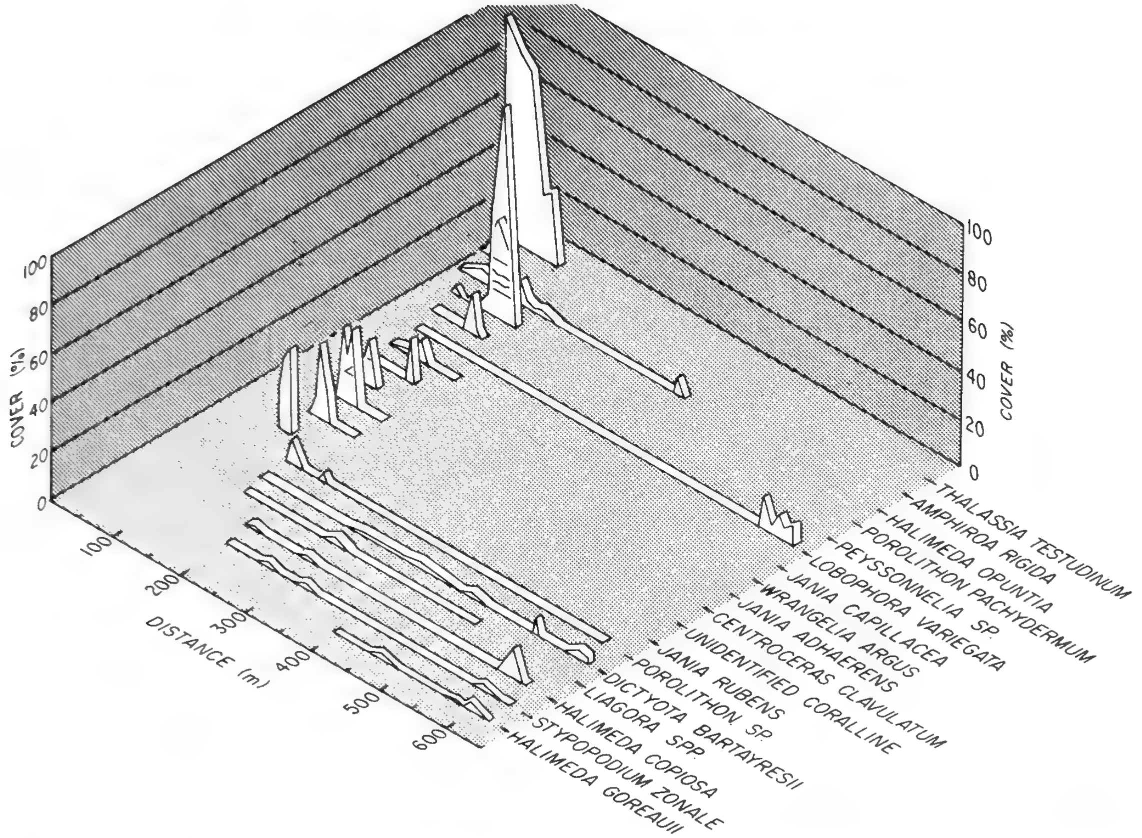

Figure 4. Distribution and abundance patterns of the major plant cover.

Figure 5. The outer portion of the shallow reef flat (zone 1) showing extensive Thalassia testudinum cover. Hydrolithon boergesenii predominates on the lower portions of the branched coral Porites porites (Pallas).

Figure 6. The zone-2 pavement area covered by a mixed microalgal turf and the coral Porites astreoides Lamarck.

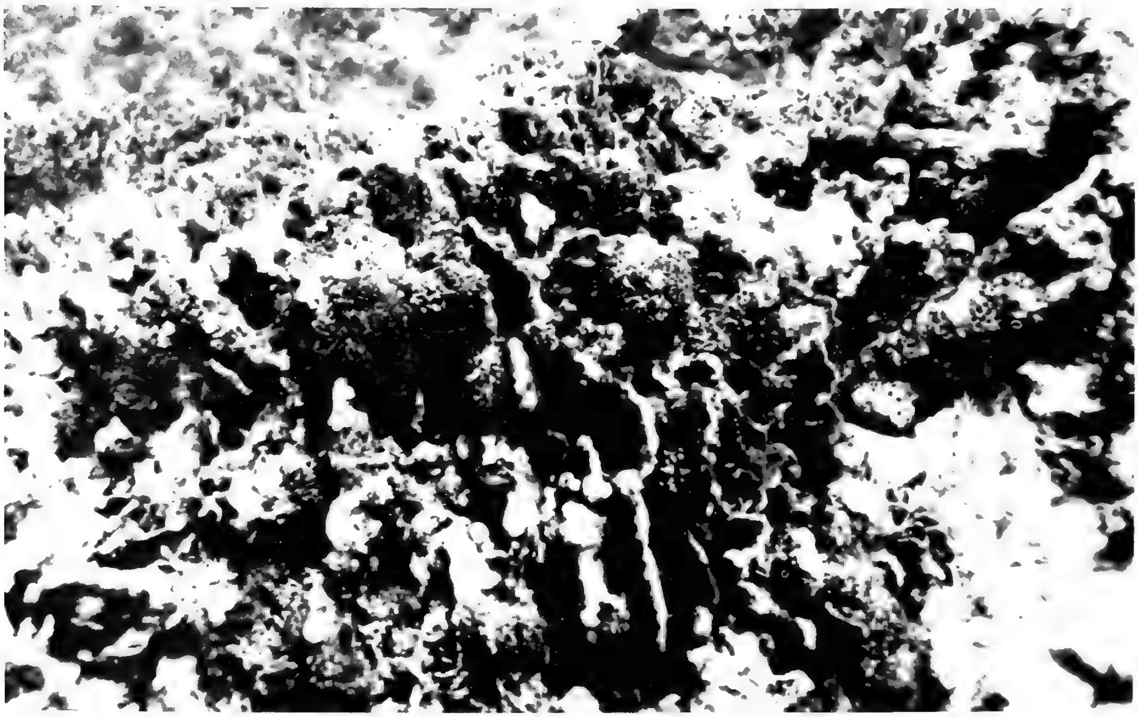

Figure 7. The shoreward portion of the reef crest (zone 3) showing coralline encrustations on the upper surfaces of the coral Agaricia agaricites (Linneaus) and clumps of Halimeda opuntia between the vertical plates.

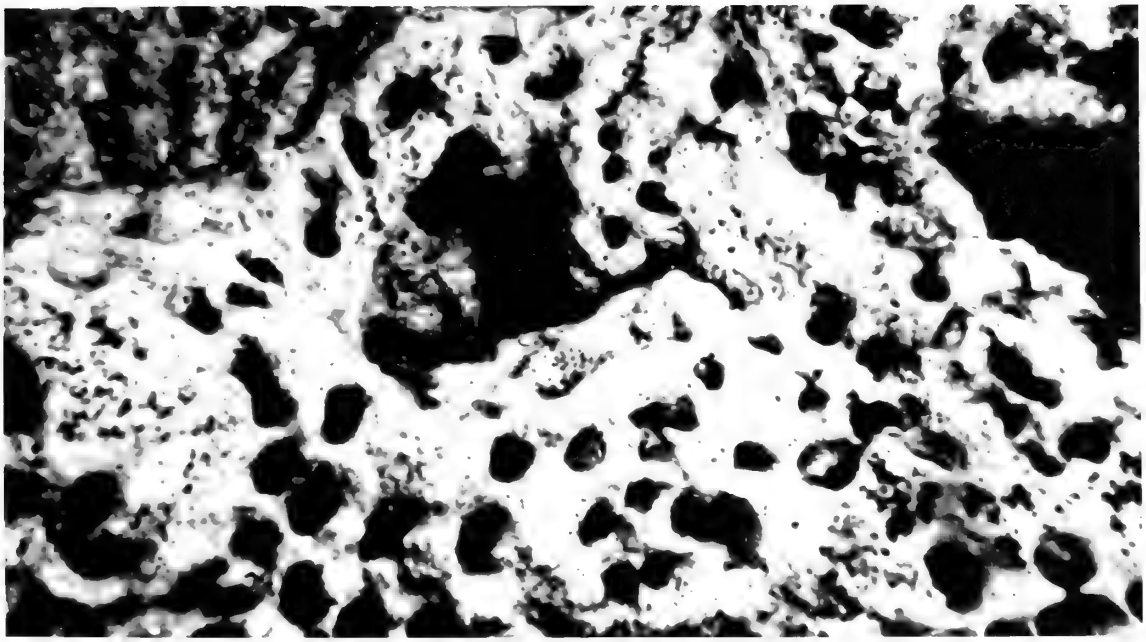

Figure 8. The Porolithon pachydermum/Acanthochitona lata association characteristic of the zone-3 reef crest.

Figure 9. View of a shallow spur in zone 4. The dead Acropora palmata (Lamarck) branches are encrusted with Porolithon sp.

Figure 10. The gorgonian-dominated lower spur-and-groove section of the fore-reef (zone 5).

Figure 11. The zone-7 reef ridge characterized by the brown alga *Lobophora variegata* encrusting dead branches of the coral *Acropora cervicornis* (Lamarck).

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ANNOTATED CHECKLIST OF THE GORGONACEA FROM MARTINIQUE AND GUADELOUPE ISLANDS (F. W. I.)

BY

PHILIPPOT VERONIQUE

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WASHINGTON, D.C., U.S.A.

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ANNOTATED CHECKLIST OF THE GORGONACEA FROM MARTINIQUE AND GUADELOUPE ISLANDS (F.W.I.)

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ABSTRACT

Seventy-five species of Gorgonians are recorded from Martinique and Guadeloupe. Twenty-two were exclusively collected during the Blake expedition (1877-1880). Fifty were recently observed by SCUBA diving and three were dredged in Guadeloupe. Among them, 13 species (Plexaura nina, Eunicea clavigera, E.knighti, E.pinta, E.palmeri, Muricea pinnata, Muriceopsis petila, Lophogorgia hebes, Leptogorgia setacea, L.virgulata, Pseudopterogorgia elisabethae, P.hystrix and Pterogorgia anceps) and 2 forms (Plexaura homomalla forma kuekenthali and Eunicea calyculata forma coronata) are recorded for the first time in the Windward Group of the Lesser Antilles.

I - INTRODUCTION

Previous works have shown the high abundance of the Gorgonacea in the West Indies. Early taxonomic studies were published by several biologists as Duchassaing and Michelotti (1860), Verrill (1883), Kükenthal (1916), Kunze (1916) and Riess (1929). Deichmann (1936) published an important monograph on the octocorallians of the West Indies region and more recently, Bayer (1961) made a general review of the shallow-water Octocorallia.

Ecological assemblages of gorgonians of several West Indies zones have been recently studied. Gordon (1925) described the communities occuring around Curaçao Islands. Guitart-Manday (1959) studied a portion of the coast of Cuba and observations upon Gorgonians living on the Mexican coast were published by Chamberlain (1966). Then, Gonzalez-Brito (1970) published a list of octocorallians from Puerto-Rico and Goldberg (1973) on the reefs of Florida. More recently, several publications increased our knowledge of the Gorgonians in the Caribbean area, with studies on the coast of Mexico (Jordan,1979), on Swan Islands in Honduras (Tortora and Keith,1980), and on Carrie Bow Cay, Belize (Muzik,1982).

From the surface to 40m, 50 species of shallow-water gorgonians were observed and collected by SCUBA diving around Guadeloupe and Martinique. The aim of the present study is to provide a first check list of the Gorgonacea from these islands.

II - THE STUDY AREAS

The two French islands are situated in the Windward Group of the Lesser Antilles and are presented in the figures 1 and 2. They are the result of the volcanic activity of the Caribbean province. The insular shelf is rather narrow. Several types of habitats can be found around these islands and can be described as follows:

1- The Caribbean coasts. (Cc)
These are the leeward coasts, protected from the dominant trade winds by the volcanic mountains both in the two islands and then, are particularly sheltered. The bottom is most often rocky and steep excepted in the bays. However, the southern portion of the leeward coast in Guadeloupe as well as the northern one in Martinique have black sandy bottoms and are often covered by shingles due to the activity of the volcanoes and the high precipitation rate.

2- The southern region of Martinique. (sM)
This zone is occupied by well developped coral reefs. However, it is more sheltered than the Atlantic coast because of the lower influence of the wind.

3- The Atlantic coasts. (Ac)
These are the windward coasts of Martinique and Guadeloupe occupied by a discontinuous fringe of reefs protecting shallow lagoons. The sea is often rough on this coast.

4- The sheltered bays. (sb)
These bays are characterized by the dominance of sandy-mud bottoms. Mangroves, when not destroyed by human activities, occupy the shore lines. Keys are numerous and their slopes may provide restricted zones of hard substrates. In Guadeloupe, the bay of Grand Cul-de-sac Marin is closed by a barrier reef (br), 20km long.

III - MATERIAL AND METHODS

The location of the stations around Martinique and Guadeloupe is shown in figures 1 and 2. The samples were collected by SCUBA diving. They were fixed in 10 per cent formalin, dried, labelled and preserved in plastic bags for storage. Most specimens were kept at the University of Pointe-à-Pitre in Guadeloupe (UAG). Moreover, several specimens were sent to the Musée Océanographique de Monaco (MOM) and to the Muséum National d'Histoire Naturelle of Paris (OCT.S). The classification of the species was based on the systematic work made by Bayer (1956).

IV - ANNOTATED CHECK LIST

Class **ANTHOZOA** Erhenberg,1834
Subclass **OCTOCORALLIA** Haeckel,1866
Order **GORGONACEA** Lamouroux,1816 (Emend.Verrill,1866)

Suborder **SCLERAXONIA** Studer,1887

Family **BRIAREIDAE** Gray,1859

Genus Briareum Blainville,1830

Briareum asbestinum (Pallas,1766)
Material: UAG, 2 specimens; MOM 120610; OCT.S.1985 18, OCT.S.1985 19.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and Martinique (sM, Ac, sb). Surface to 30m. Often dominant species where it occurs, especially on reef slopes. Often with Erythropodium .

Family **ANTHOTHELIDAE** Broch,1916
Subfamily SEMPERININAE Aurivillius,1931

Genus Iciligorgia Duchassaing,1870

Iciligorgia schrammi Duchassaing,1870
Material: UAG, 3 specimens.
Remarks: Guadeloupe (Cc) and Martinique (Cc). Often beyond a depth of 15-20m. Few low colonies in shallow-water under overhanging rocks. Just observed in relatively shallow-waters near Pigeon island in Guadeloupe. One fragment dredged at 140m deep near Basse-Terre. Larger distribution along southern leeward coast of Martinique. Usually occurs in clear waters where currents are rather strong.

Subfamily SPONGIODERMATINAE Aurivillius,1931

Genus Diodogorgia Kükenthal,1919

Diodogorgia nodulifera (Hargitt,1901)
Material: UAG, 1 small fragment.
Remarks: Guadeloupe (sb). Depth 34m. Dredged in the Petit Cul-de-Sac Marin.

Genus Erythropodium Kölliker,1865

Erythropodium caribaeorum (Duchassaing and Michelotti,1860)
Material: UAG, 2 specimens; MOM 120601; OCT.S.1985 58.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM, Ac, sb). Surface to 30m. Particularly abundant on Caribbean coasts, on reef flats and on upper outer reef slopes. Tolerates muddy environment of sheltered bays.

Suborder **HOLAXONIA** Studer,1887

Family **KEROEIDIDAE** Kinoshita,1910

Genus Lignella Gray,1870

Lignella richardii (Lamouroux,1816)
Material: UAG, small fragments.
Remarks: Guadeloupe, off Port-Louis. Depth 180m. Single species, belonging to the deep-water fauna, recently dredged.

Family **ACANTHOGORGIIDAE** Gray,1859

Genus Acanthogorgia Gray,1857

Acanthogorgia schrammi (Duchassaing and Michelotti,1864)
Type-locality : Guadeloupe, no depth given.

Family **PARAMURICEIDAE** Bayer,1956

Genus Villogorgia Duchassaing and Michelotti,1860

Villogorgia nigrescens Duchassaing and Michelotti,1860
Type-locality : Guadeloupe, no depth given. MCZ 4681, 1 specimen, Blake sta.166, off Martinique, depth 176m. MCZ 5023, 1 specimen, Blake sta.203, off Guadeloupe, depth 275m.

Genus Thesea Duchassaing and Michelotti, 1860

Thesea guadalupensis (Duchassaing and Michelotti,1860)
Type-locality : Guadeloupe, in deep waters.

T. hebes (Deichmann,1936)
MCZ 4644, 5 specimens, Blake sta.166, off Guadeloupe, depth 275m.

T. nivea (Deichmann,1936)
Holotype MCZ 4645, fragments, Blake sta.159, off Guadeloupe, depth 359m.

Genus Scleracis Kükenthal,1919

Scleracis guadalupensis (Duchassaing and Michelotti,1860)
Fragment of holotype Br.M from Guadeloupe, no depth given. MCZ 4583, 1 specimen, Blake sta.210, off Martinique, depth 350m. MCZ 4596, 2 specimens, Blake sta.203, off Martinique, depth 176m.

S. petrosa (Deichmann,1936)
MCZ 4580, 1 specimen, Blake sta.166, off Guadeloupe, depth 275m. MCZ 4581, 1 specimen, Blake sta.174, off Guadeloupe, depth 1607m. MCZ 4582, 1 specimen, Blake sta.206, off Martinique, depth 311m.

Genus Hypnogorgia Duchassaing and Michelotti,1864

Hypnogorgia pendula (Duchassaing and Michelotti,1864)
Type-locality : Guadeloupe, no depth given. MCZ 4697, 1 small specimen, Blake sta.203, off Martinique, depth 176m.

Genus Swiftia Duchassaing and Michelotti,1864

Swiftia exserta Ellis and Solander,1786
MCZ 4983, 1 specimen, Blake sta.203, off Martinique, depth 176m.

S. koreni (Wright and Studer,1889)
MCZ 4991, 1 fragment, *Blake* sta.160, off Guadeloupe, depth 720m.

Family PLEXAURIDAE Gray,1859

Genus *Plexaura* Lamouroux,1812

Plexaura flexuosa Lamouroux,1821
Material: UAG, 21 specimens; MOM 120579, MOM 120594, MOM 120598; OCT.S.1985 21, OCT.S.1985 37.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM, Ac, sb). Surface to 30m. Dominant species after *Briareum* on fore reef slopes of both islands. Also occurs on rocky habitats, on sedimentary platform of Port-Louis as well as on sandy slopes of the keys in the Petit Cul-de-sac Marin.

P. homomalla (Esper,1792)
Material: UAG, 24 specimens; MOM 120582, MOM 120583, MOM 120588, MOM 120592; OCT.S.1985 20, OCT.S.1985 38.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM, Ac, sb). Surface to 20m. Fluctuations of density quite high according to the habitat and this is more particularly noticeable in Guadeloupe: common on Caribbean coast, on reef habitat of the barrier of the Grand Cul-de-sac Marin, less frequent in the Petit Cul-de-sac Marin, very rare in the south of Grande-Terre. The 2 forms, *homomalla* and *kuekenthali* , are found in similar habitats but the latter one is more abundant.

P. nina Bayer and Deichmann,1958
Material: UAG, 5 specimens; OCT.S.1985 53.
Remarks: Guadeloupe (sb, br) and Martinique (sM). Surface to 30m. The most restricted distribution among *Plexaura* species. Mainly found in the lagoon of the Grand cul-de-sac Marin where it appears to be well adaptated to the keys near the mangrove zones. Occasionally observed in deeper waters on southern reefs of Martinique and on lower part of fore reef slope of the barrier of the Grand cul-de-sac Marin.

Genus *Eunicea* Lamouroux,1816

Eunicea asperula Milne Edwards and Haime,1857
Material: UAG, 2 specimens.
Remarks: Uncommon in Guadeloupe (sb, br) and in Martinique (Cc, sM). Surface to 17m. Small number of colonies where it occurs. Exclusively observed on the reef flat in the Grand Cul-de-sac Marin and on sandy bottoms of Petit Cul-de-sac Marin.

E. calyculata (Ellis and Solander,1786)
Material: UAG, 26 specimens; OCT.S.1985 6, OCT.S.1985 7, OCT.S.1985 8, OCT.S.1985 9, OCT.S.1985 28, OCT.S.1985 29.
Remarks: Guadeloupe (Cc, Ac, sb, br) and Martinique (Cc, sM, Ac, sb). Surface to 40m. Never reaches high densities but has a wide distribution. Also occurs on calcareous platforms. Tolerate muddy-sand bottoms (Bay of Fort-de-France, Petit Cul-de-Sac Marin). Low abundance

on all fore reef zones. Higher frequency on shallow areas of the Caribbean coasts. Seems to present more morphosis than the typical and coronata forms but the shape of the sclerites always agrees with those drawn by Bayer (1961). Coronata form rare and only found, in deeper waters of outer reef slope of the Grand Cul-de-sac Marin (25m) and of Pigeon island (40m) in Guadeloupe.

E. clavigera Bayer,1961
Material: UAG, 1 specimen.
Remarks: Guadeloupe (Ac) and Martinique (Cc, sM, sb). Surface to 30m. Single specimen collected on the south coast of Grande-Terre. In Martinique, isolated colonies where it occurs.

E. fusca Duchassaing and Michelotti,1860
Material: UAG, 2 specimens; OCT.S.1985 25.
Remarks: Guadeloupe (Ac, sb, br) and Martinique (Cc, sM, sb). Surface to 25m. Rare gorgonian occuring on outer reef slope and on inshore side of reef flat of the Grand Cul-de-sac Marin, on the south of Atlantic coast and in the Petit Cul-de-sac Marin. In Martinique, observed with the same low abundance where it occurs.

E. knighti Bayer,1961
Material: UAG, 1 specimen.
Remarks: Rare in Guadeloupe (Cc, sb) and in Martinique (Cc, sM). Surface to 20m. Isolated colonies where it occurs.

E. laciniata Duchassaing and Michelotti,1860
Material: UAG, 1 specimen; OCT.S.1985 23.
Remarks: Rare in Guadeloupe (Cc, sb, br) and in Martinique (sM). Surface to 15m. Few colonies found on the edge of the channel of the Petit Cul-de-sac Marin and only one specimen collected on the north of Caribbean coast in Guadeloupe. Isolated colonies on outer reef slopes.

E. laxispica (Lamarck,1815)
Material: UAG, 14 specimens; MOM 120585, MOM 120608; OCT.S.1985 10.
Remarks: Guadeloupe (Cc, Ac) and Martinique (sM). Surface to 40m. Rare on fore reef slopes. Very small number of colonies observed in Martinique. Common on leeward coast of Guadeloupe. Abundant on shallow platform of Port-Louis, with E. mammosa and G. mariae . Here, specimens have a smaller candelabrum-shape. In deeper waters of Pigeon island in Guadeloupe, branches are long and straight.

E. mammosa Lamouroux,1816
Material: UAG, 4 specimens; MOM 120609; OCT.S.1985 11.
Remarks: Guadeloupe (sb, br). Surface to 13m. Can reach high densities on shallow platforms (near Port-Louis, reef flat of the Grand Cul-de-Sac Marin) about 2m deep.

E. cf.palmeri Bayer,1961
Material: UAG, 6 specimens; MOM 120611.
Remarks: Uncommon in Guadeloupe (Cc) and in Martinique (sM, sb). Surface to 10m. Collected on rocky substrates as well as on the sandy slope near Port-Louis. Few colonies in the lagoon and the upper part of

the south reefs in Martinique. Specimens reported as E. palmeri doubtful because partly differ from original description. Only few spindles of the middle rind are purple, most of them being colorless. However, all other spicular and morphologic characters really fit with Bayer'description.

E. pinta Bayer and Deichmann,1958
Material: UAG, 1 specimen.
Remarks: Martinique (Cc). Beyond 30m. Never observed in shallower waters. Rare where it occurs.

E. succinea (Pallas,1766)
Material: UAG, 22 specimens; MOM 120590; OCT.S.1985 24, OCT.S.1985 27.
Remarks: Guadeloupe (Cc, Ac, sb) and Martinique (Cc, sM, sb). Surface to 25m. Sparsely distributed in Martinique. Common in the different geographical zones of Guadeloupe with high occurence on reef flat and on outer reef slope of the Grand Cul-de-sac Marin. Found with E. palmeri in front of Port Louis. The plantaginea form is more common than the typical one, but their distinction is not always easy.

E. tourneforti Milne Edwards and Haime,1857
Material: UAG, 27 specimens; MOM 120599, MOM 120600, MOM 120618; OCT.S.1985 22, OCT.S.1985 26, OCT.S.1985 30.
Remarks: Common in Guadeloupe (Cc, Ac, sb) and in Martinique (Cc, sM, sb). Surface to 20m. The typical morphosis is the most common Eunicea in both islands. Abundant on outer reef slopes, on sandy bottoms of the Petit Cul-de-sac Marin and sandy-mud area of the Bay of Fort-de-France. Highest densities observed along Caribbean coasts. Atra form rare and just found on fore reef slope of the Grand Cul-de-sac Marin.

Genus Muricea Lamouroux,1821

Muricea atlantica (Kükenthal,1919)
Material: UAG, 8 specimens; MOM 120581, MOM 120613.
Remarks: Guadeloupe (Cc, Ac, br) and Martinique (Ac). Surface to 16m. Single specimen collected in Martinique. Abondant on similar reef habitat in Guadeloupe (south coast of Grande-Terre). Isolated colonies collected on Caribbean coast and on sandy slope in front of Port-Louis.

M. elongata Lamouroux,1821
Material: UAG, 11 specimens; OCT.S.1985 56.
Remarks: Guadeloupe (Ac, br) and Martinique (Cc, sM, Ac, sb). Surface to 20m. Numerous colonies found on Atlantic coasts but quite rare elsewhere. Low number of specimens observed on reef zone of the Grand Cul-de-sac Marin. Isolated colonies occur in the Bay of Fort-de-France and on rocky bottoms of the leeward coast of Martinique. Specimens collected in deeper waters with red coloration which going out when exposed in luminous conditions. Spindles of such colonies longer than those of shallower specimens.

M. laxa Verrill,1864
Material: UAG, 4 specimens; OCT.S.1985 34.
Remarks: Guadeloupe (Cc, Ac, br) and Martinique (Ac). Surface to 20m.

Rare where it occurs. Exclusively on lower part of outer reef slope of the Grand Cul-de-Sac Marin with other Muricea spp.

M. muricata (Pallas,1766)
Material: UAG, 11 specimens; MOM 120596; OCT.S.1985 33.
Remarks: Guadeloupe (Cc, Ac, sb, br) and Martinique (Ac). Surface to 25m. Most common Muricea species in Guadeloupe. Occurs on reef slopes and rocky bottoms. Tolerate sandy-mud keys near the mangroves in the south of Port-Louis.

M. pinnata Bayer,1961
Material: UAG, 5 specimens.
Remarks: Uncommon in Guadeloupe (Ac, br) and in Martinique (Ac, sb). From 16 to 39m. Little number of colonies were it occurs. Higher abundance on Atlantic coasts. Collected in deep-waters on outer reef slope of the Grand Cul-de-sac Marin.

Genus Muriceopsis Aurivillius,1931

Muriceopsis flavida (Lamarck,1815)
Material: UAG, 7 specimens; MOM 120606, MOM 120614; OCT.S.1985 35, OCT.S.1985 36.
Remarks: Common in Guadeloupe (Cc, Ac, sb) and in Martinique (Cc, sM, Ac, sb). Surface to 40m. Distribution covers all the habitats. Density higher on rocky areas, where the sea is generally calm. Few spindle colonies found in deeper waters at Pigeon Island in Guadeloupe.

M. petila Bayer, 1961
Material: UAG, 1 specimen.
Remarks: Guadeloupe (Cc), Pigeon Island. Single specimen collected in deep-waters about -40m.

M. sulphurea (Donovan,1825)
Material: UAG, 12 specimens; OCT.S.1985 57.
Remarks: Martinique (Ac). Surface to 5m. High densities in the rough shallow-waters of the reef zones of the Caravelle peninsula and Les Salines. Colonies are more bushy under rougher conditions. The few specimens found below 3m are rather elongated and flattened. The spicules of the axial sheath of such colonies are purple.

Genus Plexaurella Kolliker,1865

Plexaurella dichotoma (Esper,1791)
Material: UAG, 17 specimens; MOM 120597; OCT.S.1985 40, OCT.S.1985 41.
Remarks: Guadeloupe (Cc, Ac, sb, br) and Martinique (Cc, sM, Ac). Surface to 15m. In Guadeloupe, abondant on shallow-waters of the northern Caribbean coast and common on shallow platforms (Port-Louis, north Pointe des Chateaux) .Its shape varies with the geographical zone: in calm waters, colonies have long and straight branches and specimens collected on Atlantic coasts are often very thick with short and crooked branches.

P. fusifera Kunze,1916
Material: UAG, 2 specimens.
Remarks: Guadeloupe (Cc, Ac, br) and Martinique (Cc, sM, sb). Surface to 20m. Apparently, less common than the above one. Samples collected with almost similar external morphology than P.dichotoma. Spiculation of the 2 species is also particularly closed. Several specimens which can be reported as P.fusifera collected in the same stations than the other one.

P. grisea Kunze,1916
Material: UAG, 8 specimens; MOM 120587, MOM 120591; OCT.S.1985 5.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br). Surface to 25m. Widely distributed in rocky bottoms, on hard calcareous platforms, on the slopes of the keys in the lagoon of the Grand Cul-de-sac Marin and with a lower density on western reef flat. Highest density on the northern part of Caribbean coast, where it is a characteristic component of the community of gorgonians.

P. nutans (Duchassaing and Michelotti,1860)
Material: UAG, 6 specimens; OCT.S.1985 54.
Remarks: Guadeloupe (Cc, Ac, sb, br) and Martinique (sM, Ac, sb). Surface to 40m. Isolated colonies where it occurs. The deepest specimen collected near Pigeon Island in Guadeloupe has a very slender form. Stout and very tall colonies occur on outer reef slopes of both islands. Hightest density along the southern coast of Grande-Terre in Guadeloupe between 10 and 20m deep. Tolerates muddy waters of the keys near the mangroves of Sainte Rose in Guadeloupe and of the Bay of Fort-de-France.

P. pumila Verrill,1912
Material: UAG, 3 specimens.
Remarks: Rare in Guadeloupe (Ac, br) and in Martinique (sb). From 14m to 25m. Isolated specimens observed in the Bay of Fort-de-France and on reef slopes of Guadeloupe.

Genus Pseudoplexaura Wright and Studer,1889

Pseudoplexaura crucis Bayer,1961
Material: UAG, 10 samples; MOM 120593, MOM 120604, MOM 120617; OCT.S.1985 2, OCT.S.1985 3.
Remarks: Guadeloupe (Cc, Ac, sb) and Martinique (Cc). Surface to 20m. Single specimen observed in Martinique. Common on rocky substrates of Guadeloupe in especially calm and clear areas. Isolated colonies observed along the south coast of Grande-Terre and on sandy slopes of the keys of Petit Cul-de-sac Marin.

P. flagellosa (Houttuyn,1772)
Material: UAG, 7 specimens; MOM 12 0605.
Remarks: Guadeloupe (Cc, br) and Martinique (Cc, sM, sb). Surface to 39m. In Martinique, rare where it occurs, especially in the Bay of Fort-de-France. Frequently observed on middle portion of leeward coast of Guadeloupe. Isolated colonies on fore reef zones of both islands and on reef flat of the Grand Cul-de-sac Marin.

P. porosa (Kouttuyn,1772)
Material: UAG, 14 specimens; MOM 120607; OCT.S.1985 4, OCT.S.1985 43.
Remarks: Guadeloupe (Cc, Ac, br) and Martinique (Cc, sM). Surface to 25m. Common on rocky substrates. Very rare in the north part of Caribbean coast in Guadeloupe. Not frequent on outer reef slopes of the southern reefs and on sandy zones of the Grand Cul-de-sac Marin. The different forms described by Bayer (1961) occur both in Guadeloupe and Martinique.

P. wagenaari (Stiasny,1941)
Material: UAG, 11 specimens; MOM 120602, MOM 120612; OCT.S.1985 1.
Remarks: Rather rare in Guadeloupe (Cc, sb, br). Surface to 10m. Occurs most often on the middle portion of leeward coast together with other Pseudoplexaura spp. Isolated specimens observed on outer reef slope of Grand cul-de-sac Marin and on north-western reef flat of Grande-Terre. Seems to be abundant in the Petit Cul-de-sac Marin but unsufficient data from this zone prevent us to draw conclusions.

Family GORGONIIDAE Lamouroux,1812

Genus Gorgonia Linnaeus,1758

Gorgonia flabellum Linnaeus,1758
Material: UAG, 2 specimens.
Remarks: Guadeloupe (Cc, Ac). Shallow-waters. Rarely collected but distinction with G.ventalina often difficult.

G. mariae Bayer,1961
Material: UAG, 7 specimens; MOM 120586; OCT.S.1985 16, OCT.S.1985 17.
Remarks: Guadeloupe (Cc, Ac) and Martinique (Ac). From 1,5 to 55m. In Guadeloupe, numerous colonies observed on southern coast of Grande-Terre, on northern Caribbean coast and on shallow calcareous platform of Port-Louis. Sparsely distributed on similar platform near Fajou island in the Grand Cul-de-sac Marin. In Martinique, abundant on similar habitat (Les Salines and Caravelle peninsula). Yellow coloration of colonies disappears with increasing of depth and tends to be pale grey or white.

G. ventalina Linnaeus,1758
Material: UAG, 9 specimens; MOM 120580; OCT.S.1985 15, OCT.S.1985 31.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM, Ac, sb). Surface to 20m. High occurence along Caribbean coasts. Common on reef flat and on fore reef slopes. Does not seem to tolerate muddy waters of the bay of Fort-de-France and of the lagoon of the Grand Cul-de-Sac Marin.

Genus Pseudopterogorgia Kukenthal,1919

Pseudopterogorgia acerosa (Pallas,1766)
Material: UAG, 15 specimens; MOM 120584.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM). Surface to 20m. Occurs on muddy shallow keys near the mangroves

(Sainte Rose and south of Port-Louis in Guadeloupe) as well as in clear waters of Caribbean coasts. Common on all outer reef slopes. Depending upon the habitats, colonies show various forms. Specimens collected from muddy-sand shallow bottoms often present a tendency to form short and widely spaced branchlets along the stems.

P. americana (Gmelin,1791)
Material: UAG, 4 specimens; MOM 120603; OCT.S.1985 14.
Remarks: Common in Guadeloupe (Cc, Ac, sb, br) and in Martinique (Cc, sM, Ac, sb). Surface to 20m. Often occurs together with P.acerosa . Abundance generally lower, except at Pigeon Island in Guadeloupe.

P. elisabethae Bayer,1961
Material: UAG, 2 specimens.
Remarks: Rare in Guadeloupe (Cc) and in Martinique (Cc). From 30 to 39m. Only two specimens collected fit with Bayer's description.

P. hystrix Bayer,1961
Material: UAG, 2 specimens.
Remarks: Guadeloupe (Cc). From 36 to 40m. Only observed on the drop of Pigeon Island. This depth range fits with that suppose Bayer (1961, p253): P. hystrix appears to be one of a non-reef assemblage made up of the deep-water representatives of the typical reef genera".

P. rigida (Bielschowsky,1929)
Material: UAG, 4 specimens; OCT.S.1985 55.
Remarks: Guadeloupe (Ac). From 10 to 20m. Uncommon species only collected along southern coast of Grande-Terre. Morphology and spiculation characters agree with taxonomical considerations given by Bayer (1961).

Genus Leptogorgia Milne Edwards and Haime,1857

Leptogorgia setacea (Pallas,1766)
Material: UAG, 2 specimens; OCT.S.1985 32.
Remarks: Guadeloupe (sb), Depth 6m. Purple specimens with several very long and flexible branches collected in muddy shallow waters, at the mouth part of the Riviere Salée in the Petit Cul-de-sac Marin.

L. virgulata (Lamarck,1815)
Material: UAG, 1 specimen.
Remarks: Guadeloupe (Cc), Pigeon Island. Depth 40m. Few colonies observed which exactly fit with the description supplied by Bayer (1961).

Genus Lophogorgia Milne Edwards and Haime,1857

Lophogorgia miniata (Milne Edwards and Haime,1857)
Material: UAG, 1 specimen.
Remarks: Guadeloupe (Cc), Basse-Terre. Depth 55m. Single specimen collected on a rocky drop. Early reported from Guadeloupe by Valenciennes (1855).

L. hebes (Verrill,1869)
Material: UAG, 1 specimen.
Remarks: Guadeloupe (Cc), Basse-Terre. Deep-waters. Single specimen collected on similar habitat than L.miniata .

Genus Pterogorgia Ehrenberg,1834

Pterogorgia anceps (Pallas,1766)
Material: UAG, 13 specimens; MOM 120589.
Remarks: Guadeloupe (Cc, Ac, sb) and Martinique (Cc, Ac). Surface to 20m. Restricted distribution in the two islands. High density on shallow calcareous platforms (Port-Louis and northern portion of Caribbean coast in Guadeloupe, Les Salines and Caravelle Peninsula in Martinique). Moderate abundance on fore reef zone of the coast of Grande-Terre and along the southern Caribbean coast of Guadeloupe. Few specimens observed on Atlantic and northern Caribbean coasts of Martinique. Reaches its highest density near the surface.

P. citrina (Esper,1792)
Material: UAG, 17 specimens; OCT.S.1985 12, OCT.S.1985 44.
Remarks: Guadeloupe (Cc, Ac, sb) and Martinique (Ac). Surface to 10m. Approximatively similar distribution than the above one, in Guadeloupe. In Martinique, Just collected on the shallow platform of Les Salines.

P. guadalupensis Duchassaing and Michelin,1846
Material: UAG, 7 specimens; MOM 120595; OCT.S.1985 13.
Remarks: Guadeloupe (Cc, Ac). From 5 to 20m. Uncommonly observed on calcareous bottoms of northern Caribbean coast. Numerous colonies collected on southern coast of Grande-Terre.

Genus Phyllogorgia Milne Edwards and Haime,1850

Phyllogorgia dilatata (Esper,1806)
Some specimens presumably collected in Guadeloupe reported as P.dilatata from literature. Bayer's doubts upon such a locality may be confirmed by the present study because no colonies of this species have been observed in that area.

Family **ELLISELLIDAE** Gray,1859

Genus Ellisella Gray,1858

Ellisella atlantica (Toeplitz,1929)
MCZ 4713, 2 specimens, Blake sta.203, off Martinique, depth 176m.

E. barbadensis (Duchassaing and Michelotti,1864)
Material: UAG, 1 specimen.
Remarks: Guadeloupe. Depth 77m. Dredged on windward coast of Basse-Terre island, off Capesterre.

E. funiculina (Duchassaing and Michelotti,1864)
Type-locality : Guadeloupe, no depth given.

_E_. _grandiflora_ (Deichmann,1936)
Holotypes MCZ 4732, 2 specimens, _Blake_ sta.210, off Martinique, depth 350m.

Genus _Nicella_ Gray,1870

Nicella _obesa_ Deichmann,1939
MCZ 4743, 1 fragment, _Blake_ sta.164, off Guadeloupe, depth 275m. MCZ 4769, 1 fragment, _Blake_ sta.166, off Guadeloupe, depth 275m.

_N_. _guadalupensis_ (Duchassaing and Michelotti,1860)
Type-locality : Guadeloupe, in deep waters. MCZ 4747, 3 large specimens, _Blake_ sta.203, off Martinique, depth 176m.

Family **CHYSOGORGIIDAE** Verrill,1883
Subfamily CHRYSOGORGIINAE Verrill,1883

Genus _Chrysogorgia_ Duchassaing and Michelotti,1864

Chrysogorgia _desbonni_ Duchassaing and Michelotti,1864
Type-locality : Guadeloupe, depth not mentionned in original description. According to Deichmann (1936) presumably about one hundred fathoms. MCZ 4837, 1 specimen, _Blake_ sta.203, off Martinique, depth 176m.

_C_. _elegans_ (Verrill,1883)
MCZ 4857, 3 specimens, _Blake_ sta.195, off Martinique, depth 917m. MCZ 4858, 1 specimen, _Blake_ sta.200, off Martinique, depth 864m. MCZ 4859, 1 specimen, _Blake_ sta.205, off Martinique 611m.

Genus _Iridogorgia_ Verrill,1883

Iridogorgia _pourtalesii_ Verrill,1883
Type-locality : Guadeloupe, _Blake_ sta. 173, depth 1343m.

Family **PRIMNOIDAE** Gray,1857
Subfamily PRIMNOINAE Gray,1857

Genus _Callogorgia_ Gray,1858

Callogorgia _verticillata_ (Pallas,1766)
MCZ 4816, fragments, _Blake_ sta.208; off Martinique, depth 388m.

Subfamily CALYPTROPHORINAE Gray,1870

Genus _Narella_ Gray,1870

Narella _regularis_ (Duchassaing and Michelotti,1860)
Type-locality : Guadeloupe, no depth given.

Family **ISIDIDAE** Lamouroux,1812
Subfamily KERATOISIDINAE Gray,1870

Genus Keratoisis Wright,1869

Keratoisis simplex (Verrill,1883)
Holotype MCZ 4886, fragment, Blake sta. 205, off Martinique, depth 611m.

Genus Lepidisis Verrill,1883

Lepidisis caryophyllia Verrill,1883
Holotype MCZ 4904, 1 specimen, Blake sta.205, off Martinique, depth 607m. MCZ 4904, fragment, Blake sta. 205, off Martinique, 611m. MCZ 4903, fragment, Blake sta. 161, off Guadeloupe, depth 1067.

V - CONCLUSION

The gorgonians are very abundant around the French islands of the Caribbean area. Observations on the distribution of the assemblages fit with Kinzie's studies (1973) which showed relations between covering by hard substrata and density of colonies.

Species richness of the fauna of gorgonians is high in both islands as 75 species were recorded. Forty-three were common to Martinique and Guadeloupe. Fifty species were recently observed by SCUBA diving and 3 were dredged in deeper waters. The 22 others are exclusively recorded from literature (without Phyllogorgia dilatata, the location of which in the Lesser Antilles is doubtful). According to the previous works (Deichmann,1936; Bayer,1961), about 106 species were recorded from the Windward Group of the Lesser Antilles. About 70% of them are therefore present in the French islands.

Thirteen species belonging to 7 genera, and 2 forms were observed for the first time in the Lesser Antilles. They include 7 species of Plexauridae: Plexaura nina, Eunicea clavigera, E.knighti, E.palmeri, E.pinta, Muricea pinnata, Muriceopsis petila and 2 forms: Plexaura homomalla forma kuekenthali and Eunicea calyculata forma coronata. The 6 other species belong to the family Gorgonidae: Lophogorgia hebes, Leptogorgia setacea, L.virgulata, Pseudopterogorgia elisabethae, P.hystrix and Pterogorgia anceps.

The shallow-water families of Plexauridae and Gorgonidae include a totality of 47 species, with respectively 32 and 15 species. Several publications also confirmed the dominance of these gorgonians in the West Indies zones (Goldberg,1973; Gonzalez-Brito,1970; Muzik,1982; Tortora and Keith,1980; Kinzie,1973). In the French West Indies, the following species are the most common ones and are widely distributed in shallow-waters : Briareum asbestinum, Erythropodium caribaeorum, Plexaura flexuosa, P.homomalla, Eunicea tourneforti, Muriceopsis flavida, Pseudopterogorgia acerosa and Gorgonia ventalina. A recent study on the distribution of the gorgonians around Martinique (Philippot, 1986) shows their strong dominance.

Gorgonians are distributed in two bathymetric ranges in the sense of Bayer (1961). The shallow-water species extend from the surface to 45m deep and the deep-water ones inhabit beyond this limit. Thirty-eight shallow-water species are recorded both in the Windward Group of the Lesser Antilles (Bayer,1961) and in the French islands.

However, 6 species of the first list were found neither in Guadeloupe nor in Martinique and 9 other ones were recently observed for the first time in these areas. Four gorgonians recorded as deep-water species by Bayer (1961) occur in more than 45m deep in the French islands: Eunicea pinta, Pseudopterogorgia hystrix, Plexaura nina and Muricea pinnata. Among the 61 deep-waters species occuring in the Windward Group of the Lesser Antilles, 24 were recorded in Guadeloupe or Martinique with dominance of the family Paramuriceidae.

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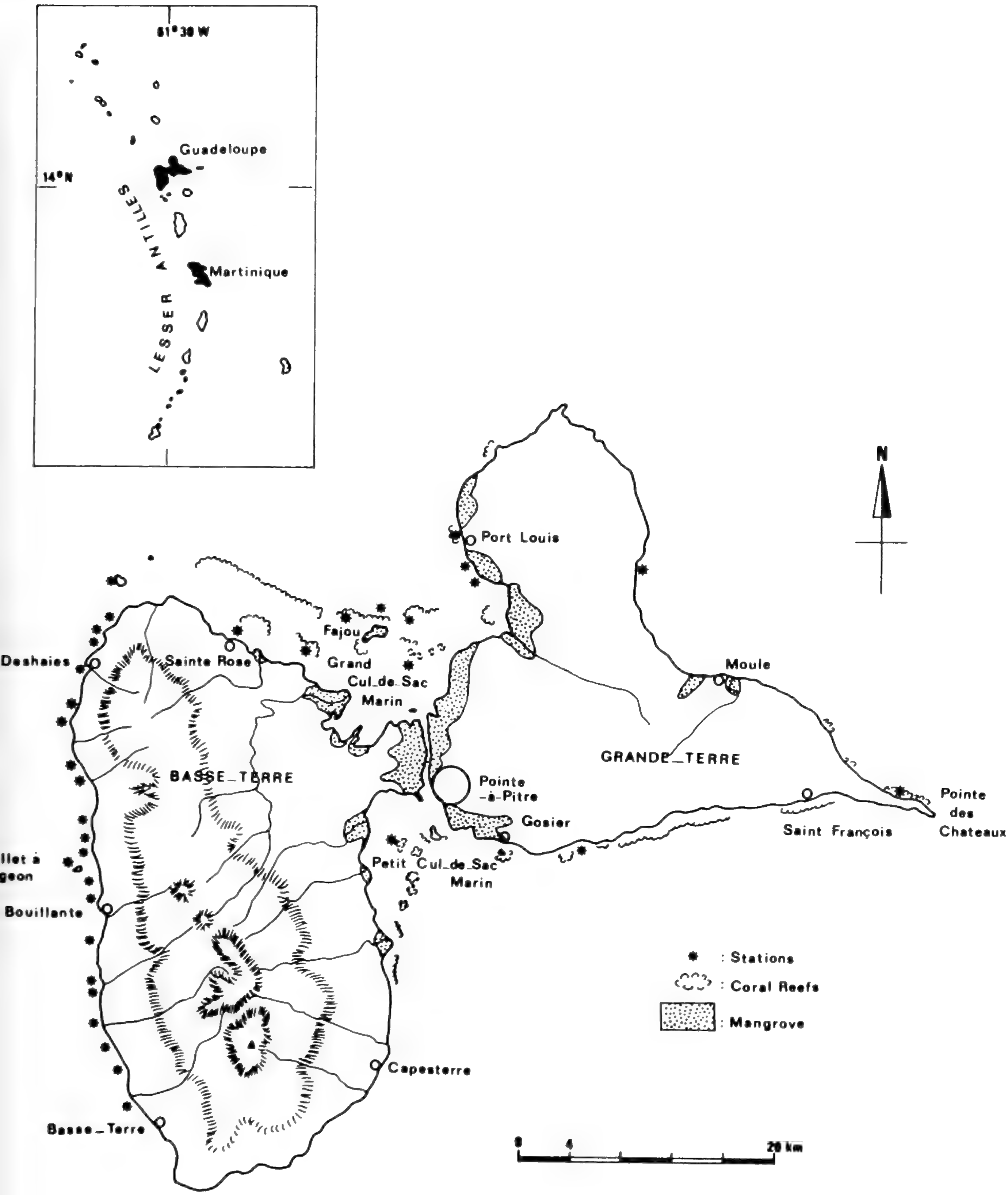

Figure 1 : Guadeloupe Island. Location of the stations.

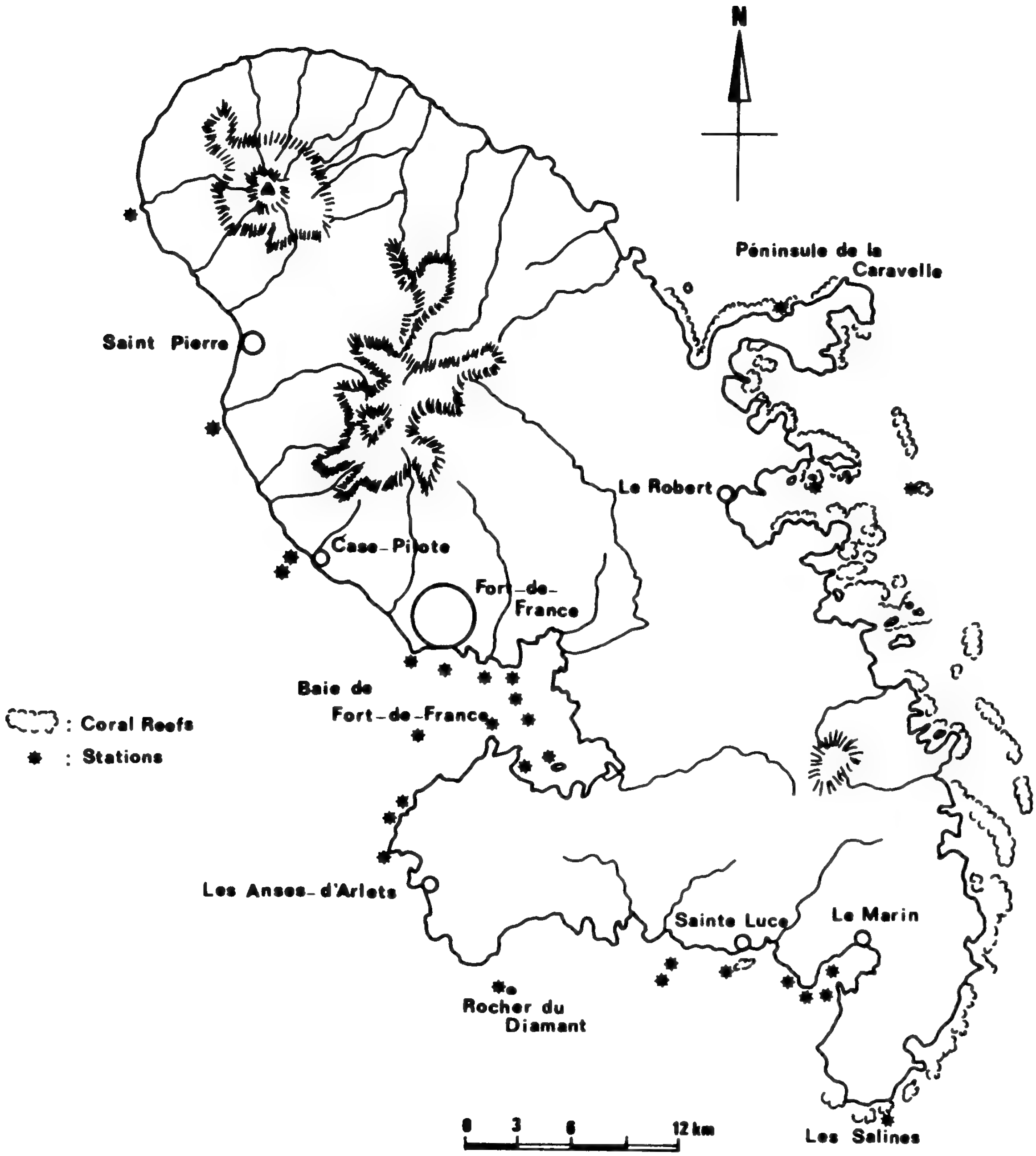

Figure 2 : Martinique Island. Location of the stations.

ATOLL RESEARCH BULLETIN

NO. 304

STATUS OF THE RED-FOOTED BOOBY COLONY ON LITTLE CAYMAN ISLAND

BY

ROGER B. CLAPP

ISSUED BY

THE SMITHSONIAN INSTITUTION

WASHINGTON, D.C., U.S.A.

AUGUST 1987

STATUS OF THE RED-FOOTED BOOBY COLONY ON LITTLE CAYMAN ISLAND

BY

ROGER B. CLAPP*

Introduction

The Red-footed Booby (Sula sula), a pan-tropical species, is one of the most abundant of tropical pelecaniform birds. Summaries of its status in some areas indicate that the species is undergoing a slow decline. Red-footed Boobies formerly bred at about 16 localities in the western Indian Ocean and at several were noted as "common". Now they are common only at Aldabra Atoll (ca. 6,000-7,000 pairs) and have been extirpated from 12 of the 15 remaining localities (Feare 1978, 1984). In the South Atlantic, they are gone from several breeding areas; now fewer than 100 pairs breed at two colonies (Williams 1984). Red-footed Boobies have declined in Indonesia and remain abundant (1,000-6,000 pairs) only at Manuk in the Banda Sea (de Korte 1984). Caribbean populations also have declined (Halewyn and Norton 1984); the Red-footed Booby colony on Little Cayman Island remains one of the largest (Table 1).

In the tropical Pacific the species is still widespread with populations on the order of 1,000-10,000 pairs each in the Society, Phoenix (Garnett 1984), and Northwestern Hawaiian Islands (Harrison et al. 1984), as well as in Fiji and New Caledonia (Garnett 1984). A population exceeding 10,000 pairs is believed to breed in the Line Islands (Garnett 1984) and about as many are thought to breed on Cocos Island (Nelson 1978). Nelson (1978) suggested that 250,000 pairs breed in the Galapagos Islands -- the home of a large proportion of the species' population. Seabird populations there have been only indifferently surveyed, however, and populations could be smaller.

In 1975, A. W. Diamond (1980) tried to determine the size of the population on Little Cayman but could not determine the size of the breeding population because his survey was made after the birds had bred. I visited Little Cayman from 17 to 27 January 1986 to survey the colony, to estimate the size of the breeding population, and to determine, if possible, whether numbers had changed since Diamond's survey.

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Table 1. Size, location, and breeding data for Caribbean Red-footed Booby Colonies[1]

Location	When Data Obtained	Colony Size (Pairs)	Breeding Data	References
Half Moon Cay off Belize	1958	1400	Laying November to April.	Verner 1961
Little Swan Id. off Honduras	1908	?	Many nesting on eastern island on 19 January	Lowe 1909
	1929		Common with variously sized young in April	Fisher and Wetmore 1931
Navassa Island	?	300+		
Little Cayman Island	1986	2600	Mostly downy young in January	This paper
Cabo Norte Puerto Rico	ca. 1975	500-700		A.O.U. 1976
Mona, west of Puerto Rico[2]	1971	1000-1400	Nests in all stages in Dec.	Raffaele 1973 in Kepler 1978
	1972	1000+	Eggs and naked young in Sept.	Kepler 1978
Monito, 5.6 km NW Mona[2]	1945	6	Nesting in April	Bond 1976, 1977
	1973	800-850	Eggs laid late June - April, in Aug.-Sept.	Kepler 1978

1. Information in this table is largely from Halewyn and Norton (1984) and sources cited therein but includes supplementary details from the literature. Colonies are listed west to east from Belize through the Lesser Antilles and east to west along the northern coast of South America. Other areas where Red-footed Boobies breed or have bred, but for which no adequate information is available include the Pedro Cays off Jamaica, the Albuquerque Cays and Serrana and Serranilla Banks in the southwestern Caribbean.
2. A combined total for these two localities of 1400 pairs is given by Halewyn and Norton (1984).

Table 1 (cont'd). Size, location, and breeding data for Caribbean Red-footed Booby colonies.

Location	When Data Obtained	Colony Size (Pairs)	Breeding Data	References
Desecheo Island off Puerto Rico	1984	150-200		Norton 1984
			Colony with ca. 2000 birds in June 1912 later reduced by depredating monkeys	Wetmore 1918 A.O.U. Conservation Committee 1976
Cayos Geniqui NE of Culebra	1981-82	3-6		Furniss 1983
Frenchcap Cay US Virgin Is.[3]	1984	3?		Norton 1985, in litt.
Dutchcap Cay[4] US Virgin Is.	1980	ca. 500	Nests and eggs in Dec.	Norton 1981a, in litt.
	1981	ca. 150?	Downy young present 11 June	Norton 1981b
Redonda Island Lesser Antilles	1980's	1000+		Norton in litt.
Grenadines Lesser Antilles		?	Present status unknown, formerly at 2-4 sites.	
St. Giles Islet Tobago	1958-66	100+	"Several hundred" nest. Eggs most frequent Aug.-Apr.	Dinsmore and ffrench 1969
	1973	750		ffrench 1973
Los Testigos Is. off Venezuela	1908	?	Nesting on 1 Jan.	Lowe 1909
	?	100's		

3. Breeding confirmed for the first time in September 1984 (Norton 1985). Furniss (1983) indicated that the species nested there previously but Norton (in litt.) states this is in error.
4. The species has also bred on nearby Sula Cay in the early 1980's but may not do so at present (Norton, in litt.)

Table 1 (cont'd). Size, location, and breeding data for Caribbean Red-footed Booby colonies.

Location	When Data Obtained	Colony Size (Pairs)	Breeding Data	References
Los Hermanos Is. off Venezuela	1908	?	Most abundant booby 8 Jan. Most with small to large downy young	Lowe 1909
	?	100's		
La Orchila off Venezuela	1909	?	Common and nesting 8 Feb. with at least eggs present.	Cory 1909
Los Roques off Venezuela	1980's?	2500	On Las Bubias In the late 1950's nested on Salesqui, Marie Uespen and Las Bubias	Meyer de Schauensee and Phelps 1978, Phelps in litt.
		2000		
Las Aves Islands off Venezuela		1200		Halewyn in litt.
Roncador Cay SW Caribbean	1969	?	"Covered with boobies in May-June but species not given.	Milliman 1969

At present Red-footed Boobies nest on Little Cayman along the north shore of a shallow pond near the southwestern shore of the island. The colony is easily visible from across the lagoon (Figure 1) where the birds may be seen roosting and at their nests in the fringing mangrove (*Rhizophora mangle*, *Laguncularia racemosa*). However, the occasionally deep mud and jagged protruding rocks (ironshore) along the lagoon on the south edge of the colony (Figure 2), together with the dense tangles of vegetation, make casual visits difficult. Although most of the nests along the northern edge of the lagoon are in mangrove, the area occupied by fringing mangrove varies considerably (Figure 3). Near transect 3 the mangrove is replaced by a fairly open forest of *Cordia sebestena* in which the boobies nest. Inland they nest in a variety of woody plants, among them

Figure 1. Red-footed Boobies nesting at northeastern edge of lagoon as seen from south shore, January 1986

Figure 2. Fringing border of northern side of lagoon, January 1986

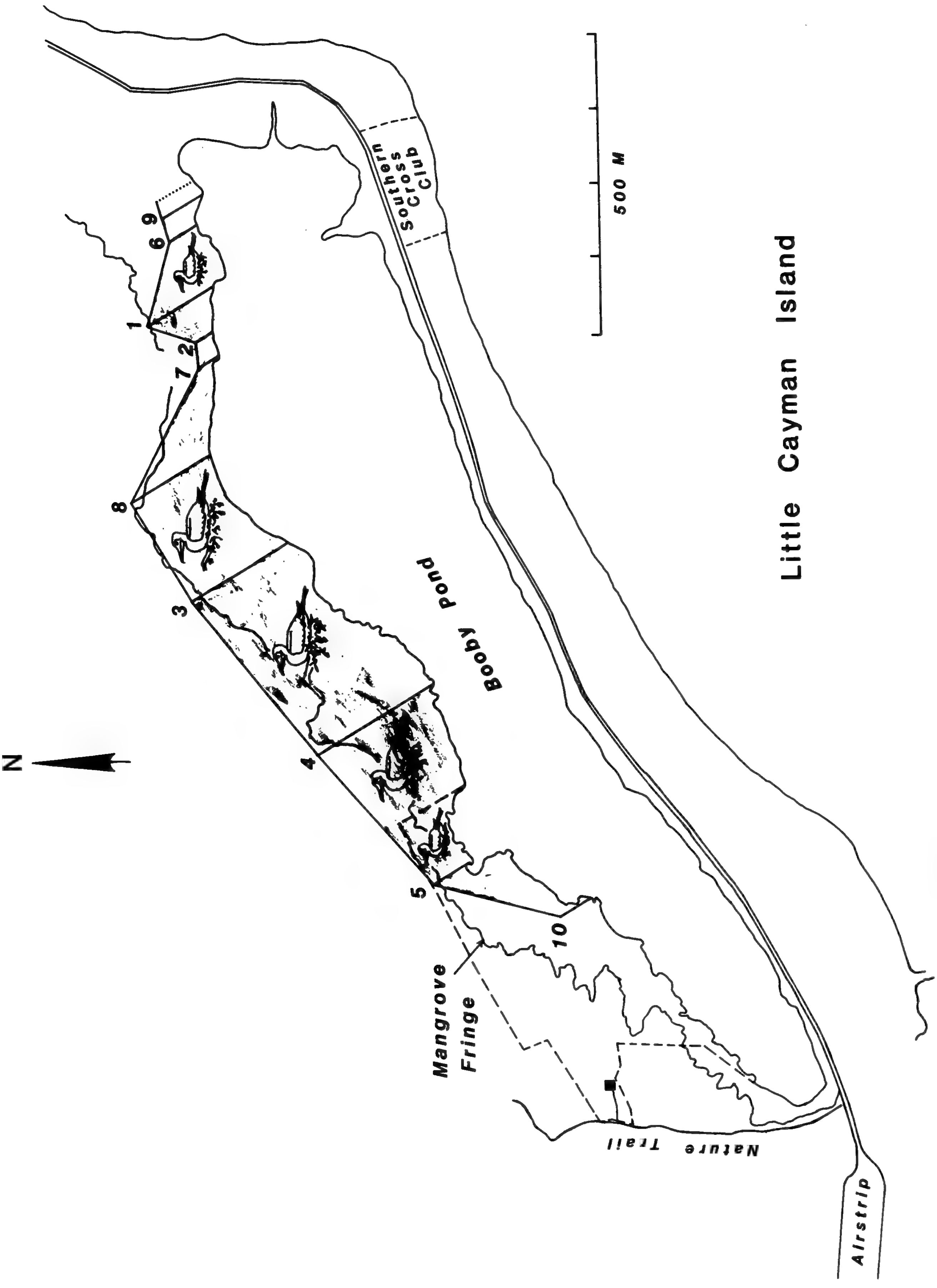

Figure 3. Area occupied by Red-footed Booby colony on Little Cayman Island. Numbers indicate individual transects.

Bumelia retusa, Bursera simaruba, Ficus aurea, Plumeria obtusa, Hypelate trifoliata, Thrinax radiata, Thespesia populnea, Guapira discolor and Canella winterana. During my visit, all nests but one were located 4 m or more up in trees made difficult the capture of birds and dermination of nest contents.

The adult population consists of two distinct color morphs - one white with black wingtips (Figure 4), the other mainly dark brown with a white tail (Figure 5). Some dark birds are more intermediate between plumage morphs than has been reported previously. The dark morph is variable with white extending as little as a few cm up the back and belly to as far as the lower breast and between the wings. Although the wings are usually brown in some birds the secondaries may be patchily white. One bird was white on the underparts well up on the chest and had a white head (Figure 6).

Nestlings and recently fledged young have black bills that gradually become pink with dark tips and finally become blue. Nelson (1978) stated that the iris of breeding adults of the white-tailed brown morph was gray in the West Indies. On Little Cayman the iris color of adults is deep brown and that of nestlings and recently fledged young is clear gray.

In the Caribbean the proportion of dark morphs in the population varies considerably from colony to colony (Table 2), but dark morphs typically compose 80-90% of the breeding population.

The 1975 Survey

From 0800-1000 on 1 August 1975, Diamond counted the number of Red-footed Boobies seen along the southern edge of the lagoon from the opposite shore. He distinguished color and size, when possible, the color morphs of adults, although he did not specify criteria for juvenile birds. His total count was 1,670, and of 613 classified by age, 486 (79.3 %) were adults and 127 (20.7 %) were juveniles.

To this total, Diamond added 2,018, a figure derived from an observed density of 31 birds in 700 m^2 that was applied to a total colony size of 45,575 m^2 (= 11.25 a or 4.6 ha). The resulting figure (3,688) was multiplied by 241/124 to allow for the fact that a count throughout the day showed that more birds were present at 0600 than during his survey. This procedure gave him a final estimate of 7,168.

Diamond's total area for the colony is based on the total area of mangrove occupied which was calculated by "tracing the area of the colony from a 1:5,000 map onto graph paper and summing the area covered." This approach would have underestimated the population, because the boobies also nest in the wooded area behind the mangroves. In addition, the total (2,018) Diamond derived from the estimate based on density should not have been added to the count (1,670) made along the edge because the former subsumes the latter. The latter error is

Figure 4. White morph Red-footed Booby at nest, Little Cayman, January 1986

Figure 5. Dark morph Red-footed Booby at nest, Little Cayman, January 1986

Figure 6. Intermediate plumaged morph, Little Cayman, January 1986

Table 2. Proportions of color morphs in adult Red-footed Boobies in different Caribbean colonies.

Colony	When observations made	% dark morph	% light morph	Sample size	References
Monito Island	5 Jun. 1969	78.9	21.1	398	Kepler 1978
Puerto Rico	19 Jun. 1973	81.5	18.5	400	"
Little Cayman[1]	30 July,	89.9	9.1	685	Diamond 1980
	1 Aug. 1975	89.5	10.5	---	"
	20 Jan. 1986	86.5	13.5	288	This paper
	20 Jan. 1986	86.8	13.2	136	"
	21 Jan. 1986	91.1	8.9	271	"
	21-25 Jan. 1986	87.0	13.0	46	"
St. Giles Is. Tobago	1958-66	90	10	--	Dinsmore and ffrench 1969

1) The first figure from Diamond 1980 is derived from counts of birds flying in to roost; the second was estimated from his census. The first figure from the 1986 census is for all adults counted along the north shore, the second for nesting adults, the third for birds flying in to roost and the fourth for nesting birds counted on transects.

almost certainly greater than the former because Diamond's count provided the basis for about 45% of his final estimate and because I found only about 5% of the colony nesting beyond the mangrove fringe. Thus it is likely that Diamond overestimated the number present.

The 1986 Survey

Methods

Because I wished to compare my results with Diamond's, I censused the colony using his methods from 0805 to 0940 on 19 January. I found it difficult to distinguish morph type from across the lagoon and suspect that I included some large downy young with the white-phase adults.

I recensused the colony on 20 January while walking along the north shore of the lagoon from 0800-1015. During this count, I distinguished color phases of the adults, noted whether or not they were on nests, and counted unattended nestlings and young birds. The latter were categorized as immatures (dark-billed, dark plumaged birds that were a few months from fledging) or subadults (birds with pink bills with dark tips and with plumage incorporating part of the adult plumage).

To determine the size of the breeding population I laid out ten transects through the colony at an angle of 310° (roughly perpendicular to the long axis of the lagoon) from 21 to 25 January. The site of eight of these transects was randomly determined. The two other transects (9 and 10) (Figure 3) were made at the east and west ends of the colony to determine the width of the colony at each end. I counted all birds and nests on each 24 ft. wide belt transect. I recorded morph color of adults and numbers of other age groups seen, whether birds were on nests, and, when possible, contents of nests. The location of these transects was recorded on a base map. Results of the transects are presented in Table 3.

On a map, the north edge of the colony was estimated by drawing lines between the ends of the transects (Figure 3). The area between the transects was then calculated. The extent of the colony occurring in the fringing mangroves also was calculated. However, because more of the transects were on the eastern half of the colony where more birds are nesting in mangrove, I suspect that the estimate of the proportion of the colony occurring in mangrove is too high.

Results

My total of 731 on 19 January is less than one-half Diamond's total of 1,670. On 20 January my total for flying birds, the total most comparable with Diamond's figure, was only 296. Doubling the number of nests found (191) and adding immature (6) and subadult (93) birds increases the total to 481, still considerably fewer than when I censused the colony from the opposite shore.

Table 3. Results of Red-footed Booby transects on Little Cayman Island, January 1986[1].

Date Jan.	Transect No.	Len. (ft)	Area (ft^2)	DP	DP/ DY	DP/ N	WP	WP/ DY	WP/ N	SDY	MDY	Sub	Imm.	Prs	Prs/ Acre
21	1	310	3720	-	1	-	-	2	-	-	-	1	-	3	35.1
21	2	80	960	4	-	2	-	1	1	-	-	-	-	4	181.5
22	3	455	5460	4	6	3	1	-	-	1	3	-	-	13	103.7
23	4	542	6504	2	6	5	-	1	-	1	3	-	6	16	107.2
23	5	143	1716	-	-	2	-	-	-	-	-	-	-	2	50.8
23	6	123	1476	-	-	1	1	-	-	-	4	-	-	5	147.6
23	7	100	1200	-	1	-	-	-	-	-	-	-	-	1	36.3
24	8	372	4464	-	4	3	-	-	-	1	4	-	-	12	117.0
		2125	25500	10	18	16	2	4	1	3	14	1	6	56	95.67
24	9	193	2316	-	1	1	-	1	-	-	-	-	-	3	56.4
25	10	136	1632	1	2	-	-	-	-	-	1	-	-	3	80.0
				11	21	17	2	5	1	3	15	1	6	62	

1. DP = dark plumage morph, WP = white plumage morph, N = nests, contents unknown, DY = downy young, Imm. = immatures, young birds with all dark bills and dark tail-feathers, Sub. = subadults = older young with pink bills with dark tips and often possessing much white in the plumage or tail. Transect 4 also contained a male Magnificent Frigatebird (*Fregata magnificens*) on an egg as well as an immature (white-headed) frigatebird.

I calculated that the present area of the colony is 23.37 acres (9.46 ha), a little more than twice the area reported by Diamond (1980). I also calculated that 5.4% of the colony (1.25 a or 0.51 ha) lies north of the fringe of mangrove. Using a density of 95.7 pairs per acre (231 pairs/ha) derived from eight random transects, I estimate a breeding population of about 2,618 pairs.

The total number using the colony is greater, as this figure does not allow for immatures and non-breeding adults. The proportion of immatures seen on the transects (12.5%) was very similar to the proportion (12.7%, n: 312) of immatures seen flying in to roost 1150-1800 on 21 January. These figures are considerably less than the proportion of immatures (24.3%) that Diamond (1980) calculated were present

in August 1975. It is likely that the difference only reflects differences in the stage of breeding between the two visits.

Using 12.5% for the proportion of immatures present, I estimate a total population of flying birds of not less than 5,985. The true figure is certainly somewhat higher, as I could not estimate the number of non-breeding adults in the colony. If dependent young are included, the number present was probably as great as 7,500 to 8,000 individuals.

Because of the several problems with Diamond's estimate, there seems little basis for determining change in numbers between 1975 and 1986. Nevertheless, if the boobies occupied the same area in 1975 as they do today, it is likely that the total population is about the same today. In any case it appears that the Red-footed Booby colony on Little Cayman is healthy with no evidence of a significant decline.

Threats to the colony

During my ten-day visit to Little Cayman, I found no evidence of human interference with the colony but P. E. Bradley (pers. comm.) stated that eggs are sometimes taken. Similar exploitation is believed to have been a primary cause of the species' decline in the Indian Ocean (Feare 1978, 1984) and is also considered a serious threat in the Caribbean (Halewyn and Norton 1984). On the evening of 21 January as I counted Red-footed Boobies coming in to roost over the western end of the airstrip, I heard repeated shots from the vicinity of the village nearby. None of the flying birds fell but several suddenly dived and were obviously attempting to evade danger. Several birds seen flying over the colony had jagged holes in their flight feathers suggesting that they had been shot. Mike Emmanuel (pers. comm.) told me that perhaps as many as 20 heavily oiled birds were once captured per year during fishing trips off the west end of the colony. Few of these birds survived. The extent to which oiling, egging and disturbance have affected the colony on Little Cayman is not known.

Recommendations

This colony is probably the largest in the Caribbean and, as such, important for potential recolonization of other areas. Much of the area where the colony is located, i.e., that portion in mangroves, is a sanctuary as it is considered a wetland of international importance by the International Union for the Conservation of Nature and Natural Resources. The extent of the colony outside this area is imperfectly known, and a more detailed assessment (perhaps an aerial survey) of the area occupied would be valuable information.

Several approaches may be taken to preserve the colony once its present perimeter is accurately determined. Areas of the colony on private lands should be purchased, these areas to include a buffer zone on which boobies do not breed but where they may do so in the

future. The colony should be fenced along its northern border to protect it from casual visitors and poachers. The status and significance of the area already set aside as a preserve should be marked with signs. Presently no information is provided for the casual visitor.

Red-footed Boobies nesting on islands in the central Pacific quickly become accustomed to the presence of humans and may be approached without disturbance to their nesting activities. The Little Cayman birds took little notice of my activities in the colony; occasional roosting birds flushed with considerable disturbance. Judicious and monitored visits to the colony by bird-watchers and nature enthusiasts would produce support for its preservation and could also provide a small source of revenue for the Cayman Islands.

Much remains to be learned about the population structure of the colony on Little Cayman, including annual and seasonal variation in numbers. The proportion of the population formed by transient roosting birds from other Caribbean colonies, the extent of post-breeding dispersal by birds from Little Cayman, and the extent of movement between colonies are also not yet known. An extensive banding program should be initiated to gather such information.

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ATOLL RESEARCH BULLETIN

NO. 305

POTENTIAL FISHERIES YIELD OF A MOOREA FRINGING REEF (FRENCH POLYNESIA) BY THE ANALYSIS OF THREE DOMINANT FISHES

BY

RENE GALZIN

ISSUED BY

THE SMITHSONIAN INSTITUTION

WASHINGTON, D.C., U.S.A.

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BY

RENE GALZIN*

RESUME

La connaissance du stock exploitable est une donnée indispensable pour toute gestion rationnelle du milieu. Dans les 110 pays possédant des récifs coralliens, les poissons récifaux occupent une place importante dans l'économie de subsistance et de marché local. De récentes estimations font état d'un potentiel de pêche commercialisable dans l'avenir de l'ordre de 6 millions de tonnes (1/10 des pêcheries mondiales), dont seulement 5% seraient actuellement exploités.

Tout polynésien étant un pêcheur qui apporte à sa famille, avec le poisson, une part importante des proteines animales dans l'alimentation; il est très difficile, en Polynésie française, d'obtenir des données fiables sur les statistiques de pêche et donc du stock exploitable. Dans ce travail nous donnons une approximation de ce rendement de pêche prévisionnel pour un récif frangeant de l'île de Moorea, en étudiant la Dynamique des Populations (biologie, reproduction, stock, croissance, biomasse et production) de trois espèces dominantes du lagon de Moorea. Si cette approche s'avère exacte, elle devrait constituer la méthode la plus simple pour estimer les productions ichtyologiques dans les récifs coralliens soumis à des pêcheries de subsistance et d'exploitation commerciale.

....

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INTRODUCTION

Recent studies have shown that many coral reefs are capable of yielding a total fish catch of 18- 24 $T.Km^{-2}$ (Hill, 1978; Alcala, 1981; Munro, 1987). There are, however, no estimates for the productivity and yield of fishes associated with coral reefs in French Polynesia. This study was designed to determine the fisheries yield from a part of the fringing reef on the island of Moorea, French Polynesia.

This area, however, has a different assemblage of fishes compared to some of the other reefs that have been studied. There are fewer species in French Polynesia due to its isolation in the eastern part of the Indo-Pacific province, and moreover, the assemblage of fishes is dominated by relatively few species (Galzin, 1986a).

In this paper, I have assumed that it may be possible to estimate the biomass and productivity of whole groups of fishes by studying the population dynamics of the dominant species. Because most fish in Polynesia fall into 3 groups viz. herbivores, omnivores and carnivores, I only collected data on three species. They are: 1/ The herbivore Ctenochaetus striatus (Quoy et Gaimard, 1824) "**Maito**". It is common throughout the Indo-Pacific (Springer, 1982), and is the most abundant species of surgeonfish in the lagoons of high islands in French Polynesia (Galzin, 1985). It is not a commercially important species, however, because it is sometimes ciguatoxic. 2/ The omnivore Stegastes nigricans (Lacepède, 1803) "**Atoti**". In French Polynesia, this species does not occur on the outer slope at depths greater than 3m, but it is extremely abundant in all the fringing reefs. **Atoti** is a pugnacious territory holder (Allen, 1975). One of its favorite habitats is dead coral colonized by filamentous algae. 3/ The carnivore Sargocentron microstoma Günther, 1859 "**Araoe**". It is the most abundant of the large nocturnally active fishes in the lagoon of Moorea island.

In this paper I present data on the biology, biomass and growth of these three species. These data are then analyzed to provide an estimate of the productivity of these fishes and, of the fisheries yield from one part of the reef of Moorea island.

MATERIAL AND METHODS

Area and duration of study. This study was carried out on the northwestern part of Moorea Island, 17°30'S; 149°50'W (Fig.1). Further details of this area are given in Galzin and Pointier (1985). All samples were collected between August 1982 and October 1983.

For the feeding habit study of Ctenochaetus striatus and Stegastes nigricans every two hours and for 24 hours, 10 fishes were

collected in a neighbouring fringing reef. An emptiness index (number of empty stomachs . 100 number of examined fishes $^{-1}$) gives some indications on the daily rythm of feeding. The Sargocentron microstoma stomach contents were only analyzed with fish captured by rotenone. The occurence index (f) is the percentage of fishes containing a special kind of prey on the number of fishes with full stomachs. Numerical percentages and percentages by weight of each prey were calculated.

The **reproduction** of these 3 fish was only studied by diving observations of the behavior and by the analysis of the monthly change of the Gonadosomatic index (GSI = Weight of the gonad . 100 weight of the fish $^{-1}$). The 1298 Ctenochaetus striatus, 1270 Stegastes nigricans and 202 Sargocentron microstoma, examined were captured by rotenone every month during 15 months.

The **total number, the biomass** and the behavior of these 3 species are different. So, in order to study the population dynamics of each species, different procedures were used. For Ctenochaetus striatus the accuracy of the diving counts (Harmelin-Vivien et al.,1985) was good enough to use this sampling method for the stock study. The biomass was calculated by multiplying the number of individuals counted by the mean weight obtained after a monthly rotenone sampling on a neighbouring reef. Stegastes nigricans is very difficult to count while diving, so three different methods were used (Galzin, 1985): a direct evaluation by diving counts and two indirect evaluations by rotenone sampling with tagging (Bailey, 1951; Schumacher et Eschmeyer, 1943) and without tagging (De Lury, 1947). Sargocentron microstoma was the least abundant of these 3 species in the fringing reef. In this case, only the monthly rotenone sampling data collected in the neighbouring fringing reef of Papetoai was studied.

The **growth** of these fish was studied with Petersen's method (1896). In 1982, Pauly justified the possibility of using this method in the case of small tropical fish. Different growth models were adjusted to the data of length frequency (linear, logarithm, power, exponential, Von Bertalanffy and Gompertz). The growth curve adopted was that of the minimum Sum of Square Deviation (SSD) between the experimental and calculated points. I estimated the duration of larval life by measuring the laps of time between the greatest spawning episode and the first settlement of postlarvae. In doing so, I assumed that larvae originating from spawnings at Moorea ended up by settling there or that major spawning episodes occured elsewhere in french Polynesia at the same time.

To obtain an evaluation of the **biologicall productivity** of each population the equations of Ricker (1946) and Allen (1950) were used:

$$P = g\,\overline{B}$$

with P = Biological production
g = Instant growth coefficient
$\overline{B}$ = Mean biomass between 2 lengths

RESULTS AND DISCUSSION

FEEDING HABITS

Maito are diurnal feeders (Fig.2). Others features of their feeding habits are: 1/ It empties its stomach in less than two hours and its intestine in less than four hours. 2/ It stays at the foot of patchreefs at night but wakes up at 5 a.m. and begins feeding at 7 a.m.. Between 5 a.m. and 7 a.m. individuals establish a feeding territory. 3/ 80% of stomach contents were inorganic materials ingested incidentally during feeding. This material is redistributed on the reef while the fish swims. 4/ 20% of stomach contents were organic materials. 70% of this was represented by diatoms and unidentified organic matter, 29% were cyanophycae (Calothrix and Lyngbia) and only 1% were macroalgae.

Stegastes nigricans was also diurnally active, with two feeding periods each day: 10 a.m. to noon and 4 p.m. to 6 p.m. **Atoti** were omnivorous with a high tendency to being herbivorous (Table 1). Payri (1982) has found that the algal turf protected by Stegastes nigricans is composed of three parts. 1/ Filaments of colonial blue-green algae (Nodularia, Lyngbia, Mycrosystis) and microphytobenthos (< 5mm). 2/ Brown algae (Sphacelaria, Ectocarpus, Giffordia) and red algae (Wurdemania, Herposiphonia, Jania) (5-10mm) and 3/ Ceramiales (Polysiphonia and Lophosiphonia (10-25mm). However, only parts 2 and 3 are activilly eaten (Lobel 1980, Payri 1982).

Araoe is a carnivore that is most active between 5 p.m. and 7 p.m. Crustaceans, mainly Chlorodiella barbata represented 75% of the stomach contents (Table 2). With increasing age, the fish eats a decreasing number of amphipods and isopods.

REPRODUCTION

There is no sexual dimorphism in the external morphology of **Maito.** Spawning of this species was observed and described by Randall (1961), Bagnis (1970) and Robertson (1983). I observed spawning on the innerslope of the barrier reef in Moorea in October 1982, one day after the full moon, at noon. Together with data on the gonadosomic index (Fig. 3), I concluded that at Moorea during 1982, this species was mature between October and February with an intense spawning period during November- December. The new body fat associated with the gonads (Fishelson & al., 1985) was found in all of the 1 745 fish examined.

Sexual dimorphism is also absent in Stegastes nigricans. Sexual maturity occured between October and April with two long spawning seasons at the beginning, and at the end, of this period (Fig. 3). Yamamoto (1979) found that sexual maturity of **Atoti** in the Ryukyus Islands was obtained at an age of two. Stegastes nigricans spawns in couples, the eggs are demersal.

There is little information about reproduction in Holocentridae (Thresher, 1986). The data on GSI show that Sargocentron microstoma spawns from December to January (Fig. 3). This spawning season (ie summer) seems to be the same for the Holocentridae in the Caribbean (Munro et al., 1973; Wyatt, 1976).

STOCK AND BIOMASS

A mean biomass of $25 g.m^{-2}$ for Ctenochaetus striatus was found during spring and summer (from September to March) and a mean biomass of $15 g.m^{-2}$ from April to August, except in June (Table 3). It should be noted, however, that the biomass of this species is not expected to be constant across microhabitats within the lagoon at Moorea. **Maito** change locations on the reef at different stages of its development. Small fish are found close to the beach and then mean length increases towards the reef (Galzin, 1985). Moreover **Maito** are always more abundant, but have a lower mean weight on the fringing reef than on the barrier reef.

The mean biomass obtained with the three methods that were used to census the Stegastes nigricans, varied between 58 and 97 $g.m^{-2}$ (Table 4). The lowest biomass was obtained by diving counts. This can be explained by the difficulty I had in counting the juveniles holding inside coral formations. Biomass of this species was greatest at the edge of the fringing reef adjacent to the channel. In this area, I counted a mean of 12 $individuals.m^{-2}$ with a maximum of biomass of 151 $g.m^{-2}$. Is seems that the population of Stegastes nigricans is relatively stable. Between 1976 and 1983, there were no significant changes in the abundance of this species on the fringing reef (Galzin, 1986b).

For Sargocentron microstoma, the nocturnal species, maximum abundance (0.16 $ind.m^{-2}$) was found on the barrier reef at dusk (6 p.m.). During the 15 months, the mean biomass was 3.5 $g.m^{-2}$ with a range between 0.9 and 9.5 $g.m^{-2}$. The maximum density and biomass was found during winter (April to August).

GROWTH AND BIOLOGICAL PRODUCTIVITY

The major spawning episode of **Maito** was recorded on the 18th of October 1982 inside the channel of Tiahura. The first juveniles (total length of 35 mm) were seen on 26th December 1982. This gives a larval life of 70 days which is quite similar to that of 75 days for Acanthurus triostegus (Randall, 1961) and 84 days for the Naso of the Great Barrier Reef (Brothers & al., 1983). The best growth curves (SSD = 0.63) were obtained with the Von Bertalanffy equation (Figure 4, Table 5). Biological productivity was calculated from the rotenone sampling data obtained during the year. The mean productivity for Ctenochaetus striatus in the fringing reef of Moorea was estimated to be 16.1 $g.m^{-2}. year^{-1}$, range 8 - 32 $g.m^{-2}.year^{-1}$(Table 5).

The two spawning periods gave rise to two main periods of larval settlement for **Atoti**. The same observation was made by Yamamoto (1979) in Japan. The best growth curves (SSD = 0.52) was obtained with the Gompertz equation (Figure 4, Table 5). Juvenile <u>Stegastes nigricans</u> settled on the fringing reef of Moorea one month after spawning. The first spawning took place in April with settlement of juveniles in May, and the second spawning occured in October with settlement of juveniles in November. My observations are in line with those of Brothers & al. (1983). They found that 14 pomacentrids from the Great Barrier Reef had larval lives of between 21 and 24 days. The mean biological productivity observed for this species was 55.6 $g.m^{-2}.year^{-1}$ (Table 5).

The present observations indicate that **Araoe** has a larval life of 60 days with spawning in December and settlement of juveniles in February at a minimum size of 25 mm. The best growth curves (SSD = 0.54) were obtained with the Von Bertalanffy equation (Figure 4, Table 5). The mean biological productivity of <u>Sargocentron microstoma</u> was estimated to be 2.6 $g.m^{-2}.year^{-1}$(Table 5).

FISHERIES YIELD

The three species that were studied made up 64% of the total number of fishes and 74% of total fish biomass on the fringing reef (Galzin, 1985). Together, these 3 species have a biological productivity of 74 $g.m^{-2}$ $year^{-1}$ and a biomass of 103 $g.m^{-2}$. A simple extrapolation gives a biomass for the total fish community of 140 $g.m^{-2}$.

This biomass is similar to that found in other coral reef areas (Table 6). For example Goldman & Talbot (1976) thought that 200 $g.m^{-2}$ was the maximum biomass that a coral reef could produce. Biomass from natural coral reefs, however, are lower than those from artificial reefs, which can reach 1 500 to 1 700 $g.m^{-2}$ (Russel, 1975; Randall, 1963).

Using the empirical equation given by Gulland (1983) I estimated the maximum sustainable fisheries yield for the fringing reef of Moorea as:

$$Y_{MAX} = X\ (Y + M\bar{B}) \qquad \text{Gulland, 1983}$$

with:

Y_{MAX}	= Greatest possible yield	Gulland, 1983
X	= Arbitrary factor set at 0.3	Gulland, 1983
Y	= Current annual catch = 10 $T.km^{-2}$	Munro, 1987
$\bar{B}$	= Mean biomass	

with also:

F	= Fishing mortality = $Y/\bar{B}$	Munro, 1987
Z	= Total mortality = $M + F = P/\bar{B}$	Munro, 1987
P	= Biological production	

with my data:

$$Z = P/\bar{B} = 74.2/103.4 = 0.72$$
$$F = Y/\bar{B} = 10/103.4 = 0.09$$
$$M = Z - F = 0.72 - 0.09 = 0.63$$

then:

$$Y_{MAX} = 0.3\ (10 + (0.63 \times 103.4)) = 23$$

$$Y_{MAX} = 23\ T.km^{-2}.year^{-1}$$

$$Y_{MAX} = 23\ g.m^{-2}.year^{-1}$$

This result is in agreement with those obtained from other coral reefs in the Indo-Pacific province (Table 7).

CONCLUSION

I have demonstrated in this paper that the estimated yield of fishes from a fringing reef in French Polynesia, based on the population dynamics of three dominant species, is similar to that recorded from other coral reefs. This estimate of 23 $T.Km^{-2}.year^{-1}$ is likely to be lower than the actual value, however, because it is based on the biological production of species that constituted only 74% of total biomass. Further research is needed to confirm that estimates of total yield based on dominant species represent the actual yield. This will be hard to achieve in French Polynesia because most Tahitians fish in a subsistance manner and so collection of fisheries statistics is impractical. The only place where it may be practical to make such a comparison is Tikehau Atoll. There, the total catch from the atoll is marketed in Papeete. I encourage verification of my method at the earliest opportunity because, if it proves reliable, it may be the simplest way to estimate the fisheries production of coral reefs subject to subsistence and artesenal fisheries.

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TABLE 1 : Qualitative study of the stomach contents of *Stegastes nigricans*.

	8 Hours			10 Hours			18 Hours			TOTAL		
	Weight of prey $mg.10^{-1}$	Weight %	f	Weight of prey $mg.10^{-1}$	Weight %	f	Weight of prey $mg.10^{-1}$	Weight %	f	Weight of prey $mg.10^{-1}$	Weight %	f
Algae	799	54.1	80%	1124	44.8	90%	300	59.8	100%	2223	49.5	90%
Sponges				60	2.4	10%	29	5.8	10%	89	2	7%
Polychaeta	97	6.6	50%	66	2.6	20%	131	26.1	10%	294	6.5	27%
Sipuncula	30	2.0	20%							30	0.7	7%
Brachyura	550	37.3	60%	533	21.2	50%	19	3.8	10%	1102	24.6	40%
Galatheidae				19	0.8	10%				19	0.4	3%
Harpactacoida				2	0.1	20%				2	0.1	7%
Gasteropoda				106	4.2	10%				106	2.4	3%
Fish eggs				600	23.9	20%				600	13.4	7%
Others							23	4.6	10%	23	0.5	3%
Total	**1476**			**2510**			**502**			**4488**		

TABLE 2 : Qualitative study of the stomach contents of *Sargocentron microstoma* fished on the northwestern fringing reef of Moorea island.

	Number of stomachs with prey	f	Number of prey	Number %	Weight of prey (g)	Weight %
Algae	12	10.6			0.127	0.4
Polychaeta	10	8.8	10	1.6	0.274	0.9
Sipuncula	5	4.4	5	0.8	0.025	0.1
Gasteropoda	23	20.4	32	5.2	0.639	2.0
Opisthobranchs	37	32.7	39	6.4	1.041	3.3
Polyplacophora	30	26.5	37	6.0	1.635	5.2
Stomatopoda	1	0.9	1	0.2	0.062	0.2
Isopoda	5	4.4	7	1.1	0.017	0.1
Amphipoda	15	13.3	25	4.1	0.025	0.1
Shrimps	20	17.7	26	4.2	0.495	1.6
Alphaeidae	18	15.9	22	3.6	4.036	12.9
Paguridae	15	13.3	27	4.4	0.524	1.7
Galatheidae	35	31.0	57	9.3	1.382	4.4
Brachyura	104	92.0	308	50.2	17.535	56.2
Fish	14	12.4	17	2.8	3.192	10.2
Others	1	0.9			0.178	0.6
Total			613		31.187	

TABLE 3 : Mean weight, abundance and biomass of <u>Ctenochaetus striatus</u> inside a 100 m^2 quadrat of the fringing reef of Tiahura at Moorea.

	1982					1983						
Fringing reef	AUG. 08	SEPT. 09	OCT. 10	NOV. 11	DEC. 12	JAN. 01	FEV. 02	MARCH 03	APRIL 04	MAY 05	JUNE 06	JULY 07
Mean Weight	26.5	66.55	51.83	57.04	52.09	56.11	42.99	73.07	30.04	37.17	61.59	32.87
Number of fish measured	42	82	34	34	49	52	133	54	75	37	15	23
Number of fish counted	53	40	46	49	46	50	47	46	47	47	54	48
Biomass ($g.m^{-2}$)	14.05	26.62	23.84	27.95	23.96	28.05	20.21	33.61	14.12	17.47	33.26	15.78

TABLE 4 : Four different ways of estimating the biomass of <u>Stegastes nigricans</u> in the fringing reef of Moorea.

		Time period	Reef area	Sampled area in m^2	Method	Number of Atoti	Number of $Atoti.m^{-2}$	Biomass $(g.m^{-2})$
Direct estimation	Diving observation	From August 82 to July 1983	Edge of the fringing reef near the channel at 240 m from the beach	100	Diving Counts	93<120<138	1.2	34.5<58<76.4
Indirect estimation	With tagging	From August to September 1975		550	BAILEY (1951)	1856<4122<6389	7.5	43.9<97<151.0
		March 1976	Middle of the fringing reef at 170 m from the beach	40	SCHUMACHER et ESCHMEYER (1943)	130<223<777	5.6	38.7<66<231.3
		June 1976		40		61<175<199	4.4	29.0<83<94.8
		July 1976		20		37<47<65	2.4	56.0<71<98.4
	Without tagging	July 1983		70	DE LURY (1947)	144	2.1	83

	Ctenochaetus striatus (Quoy et Gaimard, 1824)	Stegastes nigricans (Lacepède, 1803)	Sargocentron microstoma Günther, 1859	TOTAL FOR THE 3 SPECIES
Tahitian name	Maito	Atoti	Araoe	
Feeding habits	Diurnal herbivore (grazer) 3.15g dry food day^{-1}	Diurnal omnivore 0.39g dry food day^{-1}	Nocturnal carnivore	
Gonad development	5 months from October to February	7 months from October to April	6 months from October to March	
Spawning peaks	One in November-December	Two in October and April	One in December-January	
Eggs	Planctonic	Demersal	Benthic	
Length range of fish in mm	42 to 246	10 to 156	63 to 183	
Weight range of fish in g	1.12 to 257.79	0.02 to 97.07	3.6 to 84.7	
Length-weight relation ship	$W = 0.0111\ L^{3.10}$	$W = 0.0195\ L^{3.07}$	$W = 0.0129\ L^{3.01}$	
Growth equation (cm)	$L_t = 61.95\left[1-e^{-0.0065(t+9.17)}\right]$	$L_t = 17.54 . 0.07^{0.93^{(t+0.5)}}$	$L_t = 37.28\left[1-e^{-0.0085(t+19.86)}\right]$	
Growth equation (g)	$W_t = 3986.6\left[1-e^{0.0065(t+9.17)}\right]^{3.1}$	$W_t = 128.89\ 0.07^{3.07\ 0.93^{(t+0.5)}}$	$W_t = 692.94\left[1-e^{-0.0085(t+19.86)}\right]^{3.01}$	
Minimum longevity	6 years	4 years	5 years	
% total number of individuals	18.0%	45.7%	0.3%	64.0%
% total fish biomass	9.3%	63.1%	1.8%	74.0%
Mean biomass (B) in $g.m^{-2}$	23.2	76.7	3.5	103.4
Biomass range in $g.m^{-2}$	14.0 to 33.6	29.0 to 231.3	0.7 to 14.2	43.7 to 279.1
Biological production (P) in $g.m^{-2}.year^{-1}$	16.1	55.6	2.6	74.2
Production range in $g.m^{-2}.year^{-1}$	8.2 to 32.0	21.0 to 167.0	1.6 to 28.5	30.8 to 227.5
P/B	0.69	0.72	0.74	

TABLE 5 - Summary of the principal results obtained on the population dynamic and the biology of three dominant fish of the northwestern fringing reef of Moorea island.

TABLE 6 : Ichtyological biomass obtained in different coral reef areas.

AUTHORS	COUNTRY	METHOD	REEF AREA	WET BIOMASS ($g.m^{-2}$)
BROCK (1954)	HAWAII	DIVING COUNTS	FRINGING REEF	4<185<211
ODUM & ODUM (1955)	ENEWETAK Atoll	DIVING COUNTS and ROTENONE STATIONS	REEF FLAT	1<42<200
BARDACH (1959)	BERMUDA	DIVING COUNTS	PATCH REEF	49
CLARK & al. (1962)	RED SEA	DIVING COUNTS and ROTENONE STATIONS	FRINGING REEF	35
RANDALL (1963)	VIRGIN ISLANDS	ROTENONE STATIONS	FRINGING REEF	16
TALBOT & GOLDMAN (1972)	ONE TREE ISLAND (GBR)	EXPLOSIVES	OUTER REEF	43< <390
GOLDMAN & TALBOT (1976)	ONE TREE ISLAND (GBR)	DIVING COUNTS and EXPLOSIVES	OUTER REEF	17<87<195
GALZIN (1985)	MOOREA FRENCH POLYNESIA	DIVING COUNTS TAGGING ROTENONE STATIONS	FRINGING REEF	59<140<377

TABLE 7 : Coastal tropical water fisheries yield in the Indo-Pacific area.

AUTHORS	COUNTRY, AREA	RESULTS ($T.Km^{-2}.year^{-1}$)	METHOD
HILL (1978)	COASTAL FISHERIES SAMOA	18	FISHERIES STATISTICS
ALCALA (1981)	CORAL REEFS PHILIPPINES	24	FISHERIES STATISTICS
MUNRO (1985)	CORAL REEFS AMERICAN SAMOA	20	FISHERIES STATISTICS
GALZIN (1985)	CORAL REEFS FRENCH POLYNESIA	23	POPULATION DYNAMICS

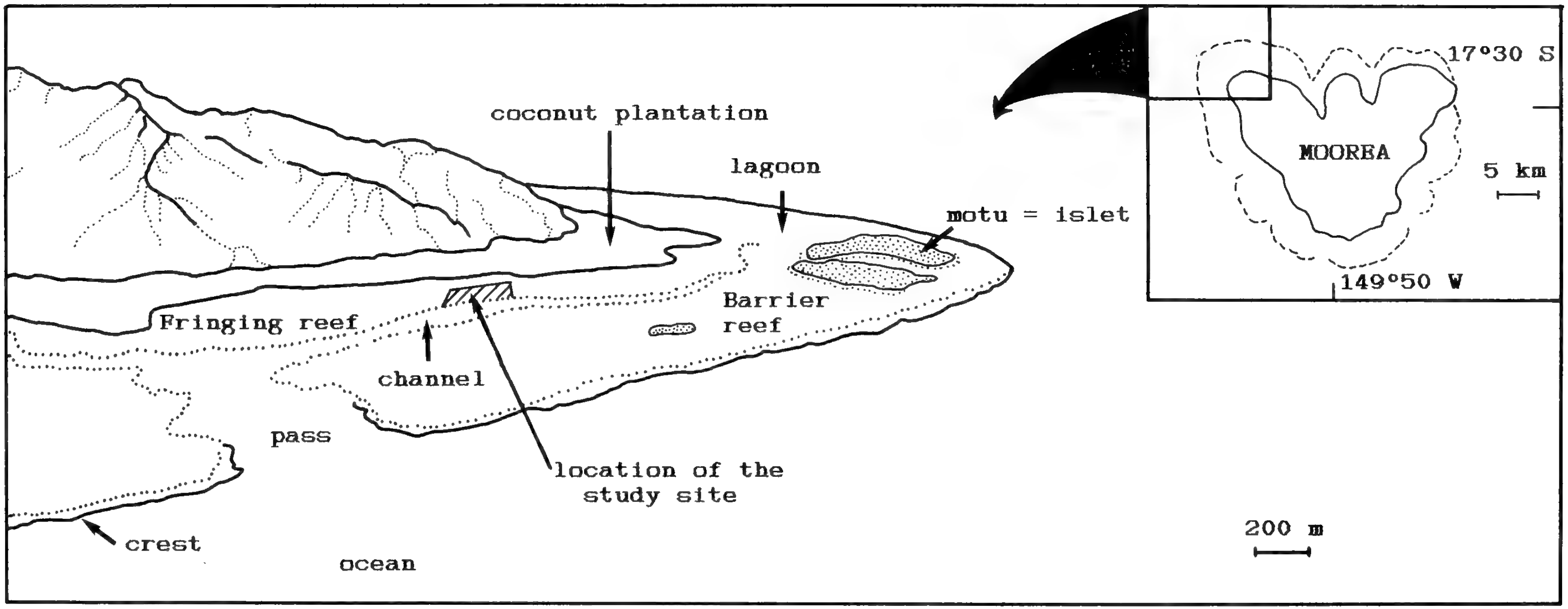


Figure 1 - The aerial view shows the northwestern part of the island of Moorea with the location of the study site on the fringing reef.

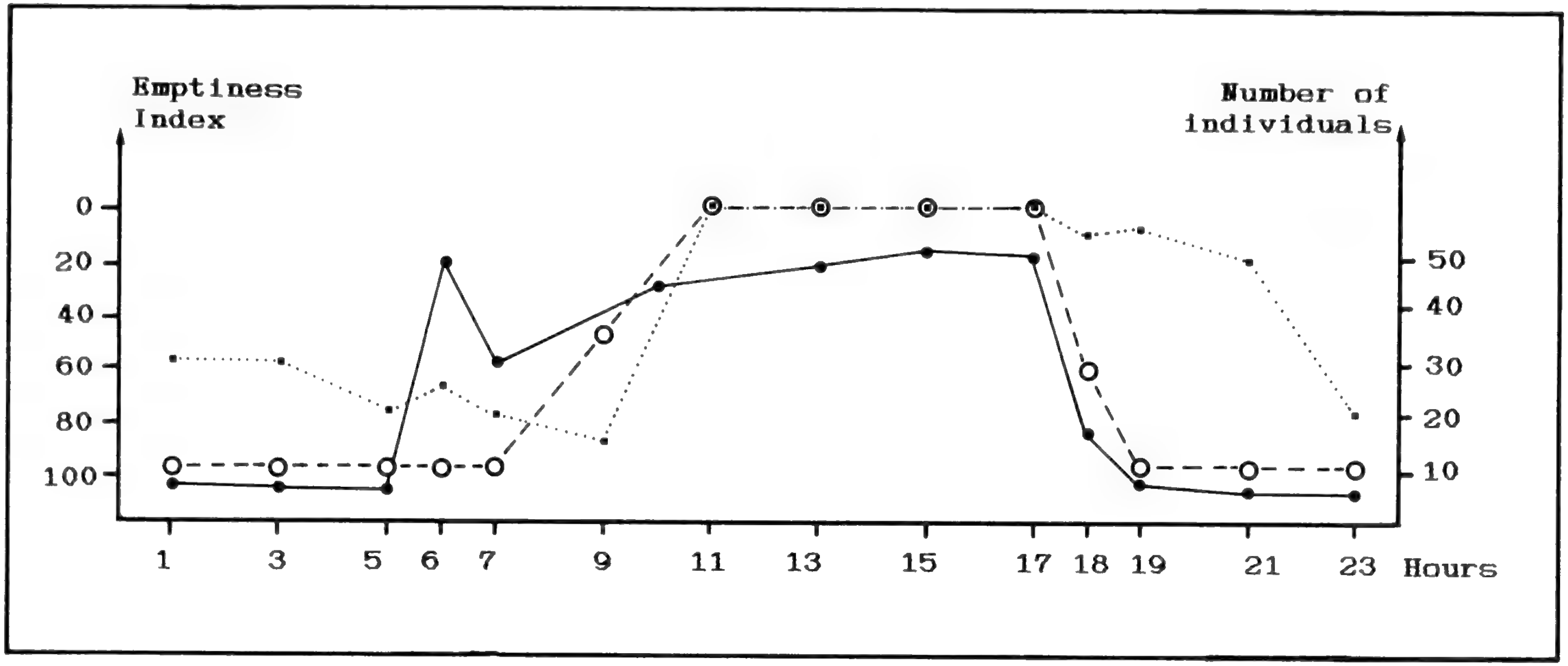


Figure 2 - 24 hours changes for the abundance and emptiness index of <u>Ctenochaetus striatus</u> fished on the fringing reef of Moorea island.

- emptiness index for stomach studies
- emptiness index for intestine studies
- number of individuals.

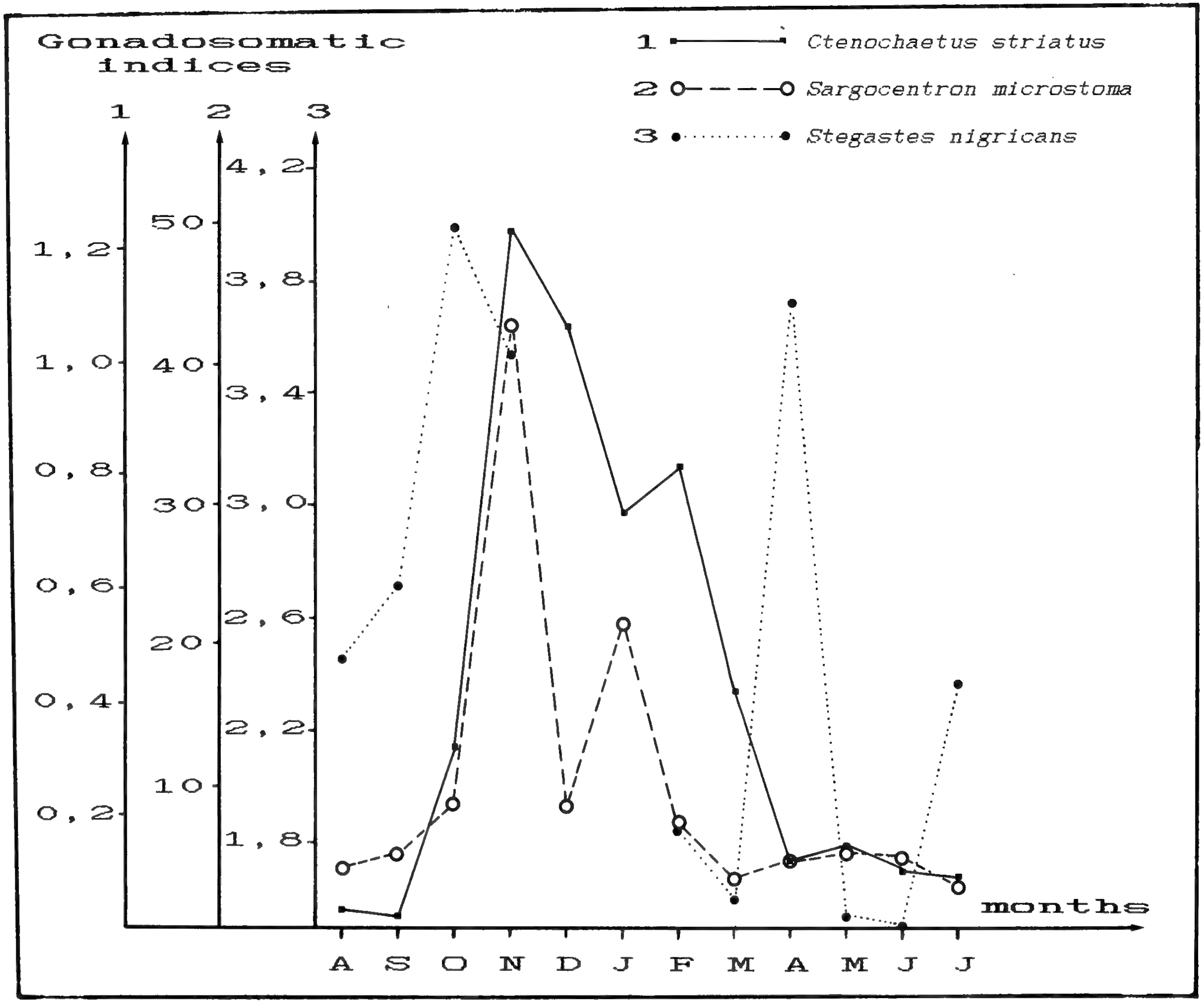


Figure 3 - Seasonal changes for the GSI of the three species fished on the North fringing reef of Moorea island.

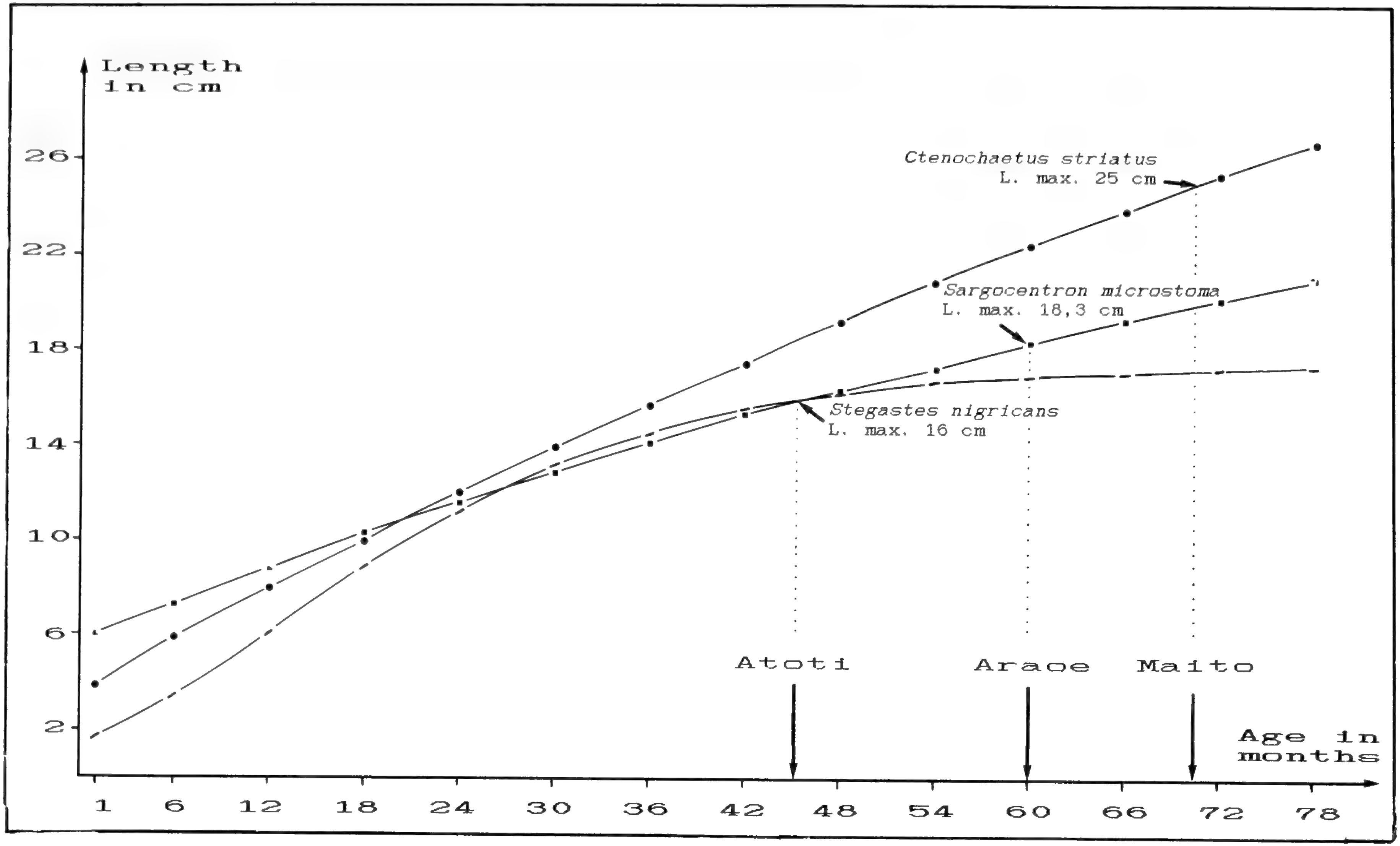


Figure 4 - Comparative length of growth curves for the three species studied on the North fringing reef of Moorea island.

Nos. 306-311 October 1987

ATOLL RESEARCH BULLETIN

306. *Effects of Feral Goats (Capra Hircus) on Aldabra Atoll*
by Bruce E. Coblentz and Dirk Van Vuren

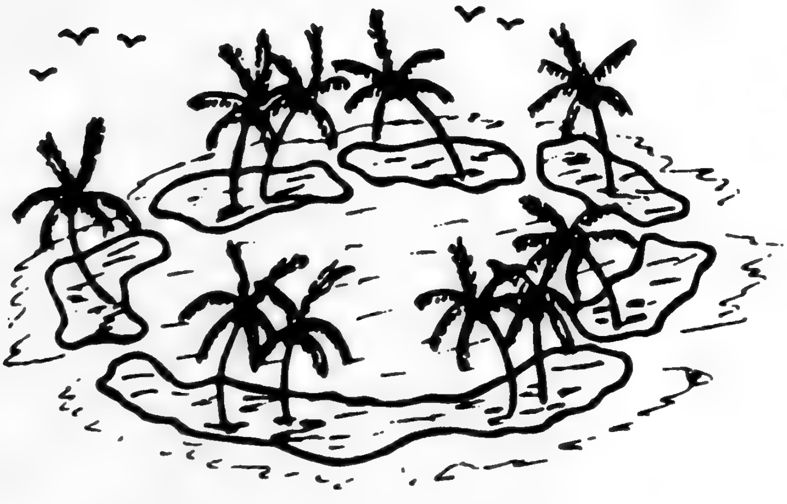
307. *Coral Species of the Indian Ocean and Adjacent Seas: A Synonymized Compilation and Some Regional Distributional Patterns*
by C. R. C. Sheppard

308. *Distribution of the Macro- and Meiobenthic Assemblages in the Littoral Soft-Bottoms of the Gulf of Aqaba (Jordan)*
by Y. Grelet, C. Falconetti, B. A. Thomassin, P. Vitiello and A. H. Abu Hilal

309. *The Decapod Reptantia and Stomatopod Crustaceans of a Typical High Island Coral Reef Complex in French Polynesia (Tiahura, Moorea Island): Zonation, Community Composition and Trophic Structure*
by Mario Monteforte

310. *Chinchorro: Morphology and Composition of a Caribbean Atoll*
by Eric Jordan and Eduardo Martin

311. *A Bibliography of Plant Conservation in the Pacific Islands: Endangered Species, Habitat Conversion, Introduced Biota*
by Robert A. Defilipps



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BY BRUCE E. COBLENTZ AND DIRK VAN VUREN

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BY C.R.C. SHEPPARD

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BY Y. GRELET, C. FALCONETTI, B.A. THOMASSIN, P. VITIELLO AND A.H. ABU HILAL

309. THE DECAPOD REPTANTIA AND STOMATOPOD CRUSTACEANS OF A TYPICAL HIGH ISLAND CORAL REEF COMPLEX IN FRENCH POLYNESIA (TIAHURA, MOOREA ISLAND): ZONATION, COMMUNITY COMPOSITION AND TROPHIC STRUCTURE
BY MARIO MONTEFORTE

310. CHINCHORRO: MORPHOLOGY AND COMPOSITION OF A CARIBBEAN ATOLL
BY ERIC JORDAN AND EDUARDO MARTIN

311. A BIBLIOGRAPHY OF PLANT CONSERVATION IN THE PACIFIC ISLANDS: ENDANGERED SPECIES, HABITAT CONVERSION, INTRODUCED BIOTA
BY ROBERT A. DEFILIPPS

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Articles submitted for publication in the Atoll Research Bulletin should be original papers in a format similar to that found in recent issues of the Bulletin. First drafts of manuscripts should be typewritten double spaced. After the manuscript has been reviewed and accepted, the author will be provided with a page format with which to prepare a single-spaced camera-ready copy of the manuscript.

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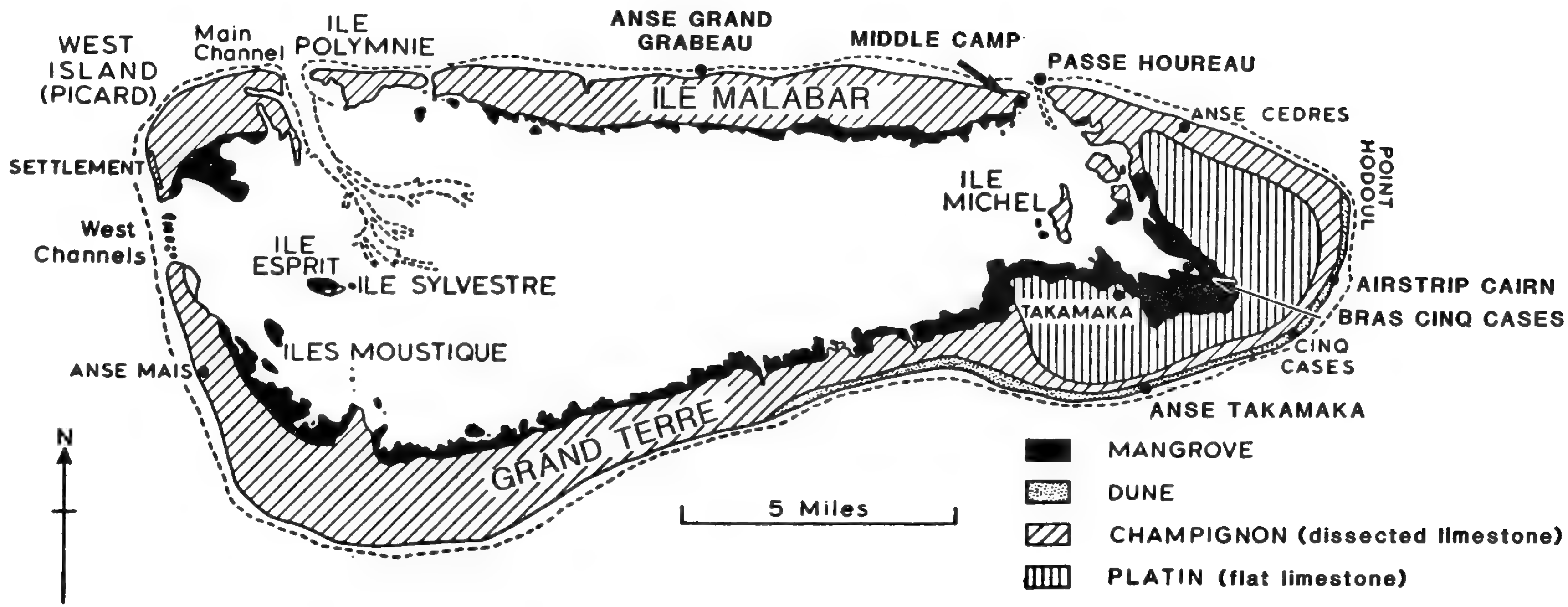
INDEX MAP OF ALDABRA ATOLL

(after D.R. Stoddart and C.A. Wright, 1967, Nature V. 213 No. 5082)



EFFECTS OF FERAL GOATS (CAPRA HIRCUS) ON ALDABRA ATOLL

BY

BRUCE E. COBLENTZ[1] AND DIRK VAN VUREN[2]

The origins of goats on oceanic islands are diverse and often poorly documented. For most populations, the date and purpose of introduction remains uncertain (reviewed by Coblentz 1978), and in any event, pales by comparison with the ecological consequences.

The earliest documented introduction of goats to an oceanic island was probably that onto St. Helena where the initial introduction occurred either in 1502 (Darwin 1860) or 1513 (Wallace 1911). The extensive damage to native vegetation resulted in an order, issued in 1731, that all stray animals should be destroyed (Darwin 1860). Nevertheless, by 1810 the island was reduced from a heavily forested condition to an oceanic rock (Darwin 1860, Wodzicki 1950). An important point concerning the destruction of the endemic forests of St. Helena was that it took a little over 200 years for the destruction to be completed (Darwin 1860). When the last of the mature trees fell, the seed sources were gone forever. In contrast, goats have only been present on Aldabra for a little more than 100 years (Stoddart 1981).

Published descriptions of the effects of feral goats in insular ecosystems have been nearly universally negative, often dramatically so (reviewed by Coblentz 1978), including destruction of native vegetation, extinction of preferred forage species, prevention of seedling regeneration, accelerated soil erosion, and numerous indirect effects upon endemic fauna, up to and including extinction (for example, Greenway 1958).

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Because of its finality, extinction seems to take precedence in the manner in which we view the effects of feral goats; however, it is to those insular species threatened, but not yet extinct that attention needs to be directed. Although a relatively few island species have been driven to extinction by feral goats (but see Thorne 1967), probably a great many more have a precarious status that is oftentimes unnoticed. High levels of grazing pressure, in addition to negative effects on favored plant species, may have dramatic effects upon invertebrate communities (Hutchinson and King 1980); the effects of feral sheep have been shown to produce marked effects upon insular avifaunal communities (Van Vuren and Coblentz 1987).

GOATS ON ALDABRA - BACKGROUND

Goats have been present on Aldabra (46°20' E. Long., 9°24' S. Lat.) since sometime prior to 1878 (Stoddard 1981); however, it is only in recent years that their presence has been viewed with alarm, and then only by some of the biologists visiting the Atoll. Although there is uncertainty about goat numbers on the Atoll during the past 100 years, they apparently have not achieved the spectacularly high densities on Aldabra as they have on other, more productive oceanic islands. However, Dupont (1929, cited in Stoddart 1981) mentioned "hundreds of them" in 1916 and "several thousands" by August 1929.

Goat numbers on Aldabra appear to have been relatively low in the past several decades (Stoddart 1971, Gould and Swingland 1980) except that they have increased markedly on Grande Terre, the largest island of the Atoll, in the past several years. Total goat numbers on Aldabra increased from an estimated 500-600 individuals in 1976-77 (Gould and Swingland 1980) to as many as nearly 1300 (Gould-Burke, M. 1986, paper given at International Aldabra Workshop, Smithsonian Institution) in 1985. The increase in goat numbers prompted concern from several biologist that some elements of the endemic Aldabra biota would be severely impacted by high levels of herbivory imposed by the goats.

Our project was precipitated indirectly by the report of Newing et al. (1984) in which data were presented indicating that goats were greatly increasing on both Ile Malabar and Grande Terre, and that on Malabar goats were spreading westward into previously unoccupied areas which were the sole habitat of the endangered Aldabran brush warbler (*Nesillas aldabranus*). In addition, although there were far more goats on Grande Terre than on Malabar, few researchers other than Newing et al. (1984) felt that there was any significant competition between the endemic giant tortoise (*Geochelone gigantea*) and the goats, although this belief seems to have been based primarily upon comparison of food habits (for example, Gould and Swingland 1980).

Thus, our project was instituted as a pilot project. Our objectives were to 1) eradicate, if possible, all goats from Ile Malabar, 2) determine if eradication of goats was possible from the entire Atoll, and 3) determine subjectively the effects of goats on major portions of the Aldabran biota. The results of objectives 1 and 2 are reported elsewhere (Coblentz and Van Vuren, 1987 unpublished report to Seychelles Islands Foundation); this paper reports our findings concerning objective 3.

EFFECTS OF GOATS ON ALDABRA

We were on Aldabra 30 January through 8 March 1987. On Ile Malabar, all accessible areas between Passe Houreau and a point about 0.5 km west of Anse Grand Grabeau were searched for goats and goat sign. Goats were shot whenever observed, and areas having sign or where goats were heard but not seen were searched repeatedly until individuals were located and killed. Subjective evaluations of goat impacts were made continuously as areas were searched for goats and sign. On Grande Terre, all habitats in an area between the lagoon at Bras Cinq Cases and the coastline from roughly 1 km north of the airstrip cairn, south and southwest nearly to Anse Takamaka, were searched for goats and examined for their effects.

Environmental damage due to goats on Ile Malabar was judged to be light. Significant effects of goats, primarily as browse lines on preferred forage species, were observed in only a few localized areas. The heaviest goat damage, and the largest area of contiguous goat habitat, was in the Middle Camp area, and much of it probably originated in past years when the population was higher (>76 in 1976-77, Gould-Burke, M., 1986, paper given at International Aldabra Conference, Smithsonian Institution, vs 32 in this study). However, even at Middle Camp there were many shrubs available to tortoises, and tortoises were frequently observed browsing.

Feral goats are severely damaging the Grande Terre ecosystem; that was immediately evident to us as we began hiking inland from Bras Cinq Cases on the lagoon side of the island. We noticed that goat sign was abundant well into the mangroves (from the land side), and that a virtually continuous browse line nearly 2 m in height was present. Even a considerable amount of *Pemphis acidula* had been completely browsed to this height, and numerous individuals had been killed.

Perhaps the greatest shock was our observation of hundreds of tortoises in intertidal areas where no herbaceous vegetation was present. At low tide we observed these tortoises to forage on the few leaves that fell to the ground, and to seemingly feed on algae on the surface of the mud. At high tide the tortoises refuged on rocks, mangrove prop roots, and dead limbs, simply to avoid being swept away; many were observed in the red mangrove (*Rhizophora mangle*) zone. It was obvious that this was a marginal, high risk habitat for tortoises, and it seemed likely that resource limitation further inland had probably been the impetus for such extensive utilization of intertidal areas.

Further inland, virtually all individuals of favored woody plant species exhibited a high browseline, and regeneration of these species was simply nonexistent. There have been several explanations offered for the dramatic changes in the flora of Grande Terre, and inexplicably they seem to search for reasons other than the goats. For example, it has been suggested that some high browselines were caused by tortoises piling up 2 and 3 layers thick while seeking shade. Presumably in such a situation a tortoise would be able to reach leaves that were not normally available. The death of large numbers of some species, for example, bois cassant (*Guettarda*) has been attributed both to tortoises abrading the roots while seeking shade, and to salt spray during storms. Perhaps these hypotheses are

correct; however, they fail to account for the complete absence of seedling regeneration, and the complete defoliation of all branches less than 2 m high. These trees all have high browselines caused by goats, and are not repopulating because seedlings cannot survive, even in areas where tortoises cannot go. Additionally, it seems unlikely that any strand species is intolerant of exposure to salt.

We do not propose that goats are solely responsible for major vegetation changes on Grande Terre, but rather that they are one major factor among several possible causes. Tortoises and their forage resource on Aldabra may well fluctuate greatly over time; it will take many years to determine if this is the case. Goats, however, greatly increase total consumption of plant biomass, and compete directly and indirectly with the tortoises for food. We believe that the impact of goats on Aldabra is additive to that of the tortoises, and magnifies the amplitude of fluctuation in numbers of both plants and tortoises, increasing the chances of extinction of the most sensitive endemics.

Changes in woody vegetation on Grande Terre are a good example of the effect of goats. Several authors (Hnatiuk et al., 1976; Merton et al., 1976; Swingland and Coe, 1979; Gould and Swingland, 1980) have presented compelling arguments that attribute recent changes in the vegetation on Grande Terre to feeding and resting activities of tortoises. The negative effects of tortoises are irrefutable; however, we believe that these effects do not account for all the damage observed. In fact, we strongly disagree that the tortoise is the "only significant primary consumer" (Coe et al., 1979) and that "The impact of feral goats on the giant tortoise is minimal on Aldabra" (Gould and Swingland, 1980). In some areas, goats probably contribute significantly to the death of shrubs, and more importantly they play a key role in preventing all regeneration of preferred woody species. Furthermore, we are certain that the nearly 2 m high browseline observed on Grande Terre is attributable solely to goats. Since tortoises presumably evolved with the vegetation of the island, it seems likely that the plant species are capable of regeneration in the presence of tortoises, at least in refugia where the tortoises cannot get to them. Goats represent the only additional major source of herbivory on Grande Terre, and are capable of going where tortoises cannot. It would seem logical to attribute the complete lack of seedling regeneration to them.

One factor supporting our argument that goats are currently a major competitor for forage on Grande Terre is the density of goats we observed. Gould and Swingland (1980) reported a density of 10-12 goats/km^2 in the southeast portion of Grande Terre. Working in the same area, we killed 292 goats in an area of about 8-10 km^2, and many more remained alive. Thus, there were in excess of the 29.2-36.5 goats/km^2 based on kill figures alone, a minimum three-fold increase in the decade since the 1977 (Gould and Swingland, 1980) estimate.

By contributing to the accelerated death of trees and shrubs, and preventing all seedling regeneration, goats may be severely limiting the amount of shade available to tortoises. Additionally, as foliar area of a plant is reduced through browsing, the number of tortoises that can refuge under that plant is proportionately reduced; excess tortoises need to find a new source of shade. In some areas, sources

of shade are far apart and essentially fully utilized, thus tortoises forced to seek new shade probably have a low probability of survival. The effects of goats upon the shade resource may actually be a greater influence upon tortoise numbers and condition than direct competition for food.

Accordingly, we have concluded that there should no longer be any question of whether goats should be eradicated, but rather a question of how soon it can be implemented. Together we have many years of experience with feral ungulates on oceanic islands, and we judged the impacts of goats on Grande Terre to be as serious as other islands where goats have been viewed as agents of habitat degredation and extinction of endemic species. Quite clearly in our minds, goats on Grande Terre are altering the species composition of both fauna and flora, reducing the forage resource available to tortoises, eliminating seedling regeneration, reducing shade available to tortoises, and probably reducing biotic diversity.

On St. Helena, it took over 200 years before "the evil was complete and irretrievable" (Darwin 1860). Aldabra would better be remembered as testimony for successful preservation of insular biota, rather than a requiem for one of the world's truly unique ecosystems.

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ATOLL RESEARCH BULLETIN

NO. 307

CORAL SPECIES OF THE INDIAN OCEAN AND ADJACENT SEAS: A SYNONYMIZED COMPILATION AND SOME REGIONAL DISTRIBUTIONAL PATTERNS

BY

C. R. C. SHEPPARD

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CORAL SPECIES OF THE INDIAN OCEAN AND ADJACENT SEAS: A SYNONYMIZED COMPILATION AND SOME REGIONAL DISTRIBUTIONAL PATTERNS

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ABSTRACT

A list is provided of hermatypic coral species from 24 locations in the Indian Ocean and its peripheral seas and gulfs. Six sites are newly reported or expanded accounts, and eighteen are derived from recent literature. This is intended: (1) to provide in one place, a uniform compilation of coral species from different areas and from many diverse accounts; (2) to apply synonyms to all sites in a consistent way for the first time, so that; (3) regional analysis at species level is possible. Synonyms are taken mainly from two recent taxonomic series, but because species stability is poor in some genera and authors may differ in their views on synonymy, all names are shown. The sources of data were selected to reduce problems inherent in using diverse material, and many sources themselves include compilations and synonymys of much older works. From 796 entities initially obtained, the removal of synonyms and entries named "spp" leaves 439 species. Further reduction is probably needed. Species rich sites extend across the Indian Ocean, with no westerly decline from South East Asia; the Red Sea as a whole contains the most species. Cluster analysis shows geographical groupings in the Arabian Gulf/Arabian Sea area, in the Red Sea and in the southwest and central Indian Ocean island areas. Of these, the Arabian Group is the most separate. A second analysis corrected for diversity differences also shows three clear groups: a northern one from the Red Sea to Sri Lanka which includes the Arabian group; a large southern or equatorial region; and a group consisting of the Mergui, Nicobar and Andaman islands in the Bay of Bengal.

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INTRODUCTION

To date, most wide scale, comparative work on corals in the Indian Ocean and its peripheral seas and gulfs has been done at the generic level (Stehli and Wells 1971, Rosen 1971, Scheer 1984). Veron (1985a) also shows generic diversity contours in the Indian Ocean, but remarks that this level is inadequate for several purposes and he uses species to discuss distributions in the west Pacific. Emphasis on genera has been partly because stability at generic level is good whereas at species level it is much less so, but also it is due to the difficulty of obtaining comparable and reliable lists of species from a sufficient number of localities. Nevertheless, the species level is arguably the only biologically meaningful one since higher taxonomic levels are largely synthetic, and moreover, work at generic level has the important drawback of treating all genera as equivalent regardless of whether they contain one or a great number of species.

In the last 15 years taxonomic accounts and lists of corals at species level from the Indian Ocean have become more numerous although they are widely dispersed in the literature. Their increase has partly been due to a dramatic improvement in the literature available for coral identification, especially from the taxonomic series of Veron and co-workers and of Scheer and Pillai (Veron and Pichon 1976, 1980, 1982, Veron et al 1977, Veron and Wallace 1984, Scheer and Pillai 1974, 1983, Pillai and Scheer 1976).

An earlier plot of diversity contours at species level (Sheppard 1983) showed that there is a much smaller and less regular drop in diversity away from the east Asian region than is seen at generic level. The plot was not based on fully synonymised lists but it suggested that, numerically at least, the Indian Ocean might be more uniform than the Pacific, a point also made by Veron (1985a). Since then, new or expanded lists have become available for at least six more areas in previously poorly known parts of this region. Also it is still the case that different formats and use of synonyms by different authors makes regional comparisons unnecessarily difficult. To help overcome this therefore, the present list was compiled to include accounts, in a uniform manner and using the same synonyms, from a total of 24 Indian Ocean sites. The full listing is given here in order to facilitate further work at species level, and the result of an initial analysis of the data is reported.

In the Indian Ocean generally, knowledge of coral faunas remains patchy. Very large areas of coast are scarcely visited and many vast, shallow limestone banks and atoll groups are completely unstudied. Recently, descriptions of all known, important coral reefs in the region have been compiled into one volume (Sheppard and Wells in press), but this focuses on the nature, condition and conservation status of reefs and excludes any significant treatment of the coral species themselves. The present work therefore, is also intended to complement the volume by providing data on coral species, to the extent that this is possible at the present time.

METHODS

Sources of material and the species list

Table 1 lists those sites from which substantial lists of coral species have been obtained. Most of them have been examined within the last decade, and only the account from Cocos Keeling is older than about 15 years. Most importantly, in many cases the references given are themselves revisions and compilations to a considerable degree of preceeding work, including records from the classical expeditions. From these, a list was compiled of 796 coral species, including those refered to as "sp". Details of the number of species recorded from each site before and after synonymising is shown in Table 1. To this list the synonyms given by the above mentioned taxonomic series were applied, and unnamed species removed. The result is Appendix 1. Genera are ordered taxonomically after Wells (1956) with later additions, and within each genus, senior synonyms are listed alphabetically. Beneath each senior synonym are its junior ones, indented two spaces. The only names which have been used in the past but which are not necessarily included here are those used by some of the earlier investigators and which were synonymised by the authors shown in Table 1 in their own lists. Inclusion of such names would extend the list to around 1000 names, most of the extras being long abandoned.

For the compilation some simple rules were followed. While lists of synonyms from both main series of taxonomic monographs were used, where disagreement occurs the position of species here often follows that suggested by Scheer and Pillai since their Indian Ocean context may be more applicable than an eastern Australian one in this case. In some cases, and particularly in the Red Sea and Arabian Gulf areas, a personal opinion was sometimes made instead. However, all 678 names are given here so that future workers may judge or use the list according to their own opinions.

Secondly, areas were regarded as discrete sites only if they were obvious geographical units, such as an island group, or when they were separated from other areas by about 500 km or more in contiguous areas. For example, Maldives data are pooled although source material tabulates species from separate atolls, and likewise, the reefs of Sri Lanka, Palk Bay and southern Mandapam form a contiguous area and are also pooled. This reduces the number of sites for which data is available but ensures that a more complete list is provided for each of them. This was done because fairly complete lists are required for any regional pattern extraction, even at the expense of fewer sites. One addition to this listing is in the first column of data which tabulates all species known from the Red Sea; it is based on the monograph of Scheer and Pillai (1983) which incorporated numerous earlier works, most notably that of Head (1980), and includes data from columns 2-4 as well.

Thirdly, where only a very brief and clearly incomplete species list exists for a location then that location was generally excluded. Two exceptions were made for important geographical gaps. These are Cocos

Table 1. Sources of data for the species list of Appendix 1 with some site details. First column is site location (see figure 1). Second column ("Col.") indicates the column number of data in Appendix.
Column A: Total number of species recorded, ie including redundant synonyms and species marked as "spp".
Column B: Probable number of separate species at each area, ie after synonymising but including species recorded as "spp".
Column C: Total number of names used, ie before synonymising, but excluding "spp".
Column D: Number of names, after synonymising and excluding "spp".

Site	Col.	Location	Sources	A	B	C	D
A	1	Total Red Sea	Scheer & Pillai 1983, Head 1980, Mergner & Schuhmacher 1985, (+ cols 2-4)	257	244	235	220
B	2	Gulf of Eilat	Loya & Slobodkin 1971, Scheer & Pillai 1983, Scheer pers. comm.	146	136	144	134
C	3	Yanbu, Saudi Arabia	Sheppard & Sheppard 1985 and unpubl.	146	146	134	134
D	4	South Red Sea	Sheppard 1985b and unpubl.	109	109	94	94
E	5	Arabian Gulf	Burchard 1979, Sheppard 1985a	62	60	40	38
F	6	Gulf of Oman	Sheppard & Salm in press	61	61	53	53
G	7	South Oman	Sheppard & Salm in press	54	54	51	51
H	8	Gulf of Kutch	Pillai et al 1980	17	17	14	14
I	9	Kenya/Tanzania	Hamilton & Brakel 1984	128	118	122	112
J	10	Mozambique	Wijsman Best et al 1980, Boshoff 1981	185	153	181	149
K	11	Tulear	Pichon 1978	135	119	129	113
L	12	Aldabra	Rosen 1979	90	84	89	83
M	13	Seychelles	Wijsman Best et al 1980, Pillai et al 1973	114	107	108	101
N	14	Southeast India + Sri Lanka	Pillai 1971a ,1972, Mergner & Scheer 1974	159	131	158	130
O	15	Lakshadweep	Pillai 1971a, 1971b, 1972	72	66	70	64
P	16	Maldives	Pillai & Scheer 1976, Pillai 1972	214	166	209	161
Q	17	Chagos	Sheppard 1981, LeTissier unpub.	195	185	178	168
R	18	Reunion	Bouchon 1981, Faure 1977	155	135	147	127
S	19	Mauritius	Faure 1977	177	141	172	136
T	20	Rodriguez	Faure 1977	105	89	103	87
U	21	Cocos Keeling	Wells, 1950	67	57	66	56
V	22	Nicobars, Andamans	Pillai 1972, Scheer & Pillai 1974	129	120	129	120
W	23	Mergui	Pillai 1972	43	41	43	41
X	24	Thailand	UNESCO/UNEP 1984	205	201	205	201
[		W. Australia	Veron 1985b	-	-	-	276]
TOTAL				796	-	678	439

Keeling (56 known, named species) and the Seychelles. Data available permit a division into "Seychelles", which mostly includes the granitic islands, and Aldabra, although both are clearly very incomplete. In view of the interest given to these areas terrestrially and intertidally, as well as of the huge area of ocean that they cover, their corals are remarkably poorly studied. With the Arabian Gulf, Gulf of Oman and south Oman, the lists are short but are probably relatively complete for these marginal areas (Sheppard and Salm in press).

Data analysis

Preliminary analyses involved a cluster analysis where sites were entities and species were their attributes. The data are binary, so the Dice or Sorensen similarity coefficient was used. This is similar to the more common Jacard coefficient but doubly weights shared positive attributes (joint presences). In cases where there may be relatively few joint presences it is more suitable than Jacard's coefficient (Clifford and Stephenson 1975), and where the sites vary widely in the number of species they contain it is more intuitively accurate (Boesch 1977). It ignores joint absences, and it is also the direct binary equivalent of the most common quantitative measure, the Bray Curtis. Clustering was then carried out by the simple group averaging method, where upon fusion, the coefficients of two sites or groups of sites are replaced by their arithmetic mean.

Following this procedure, a second analysis was run with a coefficient devised to bring out other aspects of the numbers of species held in common between each pair of sites. This is intended to overcome apparent separations of areas caused by wide differences in diversity, and is described in the next section.

RESULTS AND DISCUSSION

The data set

The process of synonymising almost halves the multitude of original names to 439 species (Appendix 1). Even so, this is undoubtedly an incomplete reduction. Also, further work will suggest the transfer of some names, and the reinstatement of other species presented here as junior names.

There are at least two drawbacks with species lists. These are firstly, the problem of synonyms and the fact that lists from different areas of the Indian Ocean were published at different states of completion of the two major series of taxonomic revisions refered to earlier. Both series of revisions have now provided substantial lists of synonyms which ecologists may use to advantage, in addition to improving the means for coral identification itself. The second problem is the question of the reliability of identifications given by each author, particularly with the highly speciated genera. A solution of the first of these problems is one intention of the present listing. The second problem, that of incorrectly identifying and reporting the presence of a species, is more intractable, because apart from simple

errors, different authors do not always agree on nomenclature. However, inspection of Table 1 will show which sources have been used for each site. Another point to be considered is the degree of completeness of each species list. Probably no species list is complete, but several earlier accounts deal only with shallow water corals. Shallow areas of reefs contain only poor subsets of their total coral composition and so accounts of this kind have generally been excluded. This is a problem of reef ecology generally and not only of this data set.

The analysis

Figure 1 shows the number of hermatypic coral species known to exist at each site included in this study, using the synonymised list. Even if the total number of 439 species is still too high, the number of species shown for any one site is probably low in several if not all areas due to incomplete sampling. The totals in figure 1 indicate that species rich sites in this region may contain from 100 to more than 200 hermatypic species and that some peripheral areas to the north may support considerably less. It also shows that there is no obvious reduction in diversity as distance increases westwards from the high diversity east Asian region, and that the Red Sea is particularly rich with at least 220 hermatypic species.

The results of the first cluster analysis is shown in figure 2. Deeply shaded areas both on the resulting dendrogram and its corresponding map enclose sites which fuse at similarity levels of greater than 0.6. At this level four groups exist: all the Red Sea sites; two sites in the northwest Arabian Sea; Aldabra with Tulear and Chagos; and the three Mascarene islands. These groupings may be considered to show the existence of four areas each with a greater level of homogeneity within the Indian Ocean region.

Sites which fuse at a similarity level of >0.5 are enclosed by light shading. The Red Sea fuses with the southwest Indian Ocean sites, to form a large grouping which extends across the equatorial part of the Indian Ocean to include the Maldives, south India and Sri Lanka. Thailand and the Andaman and Nicobars sites also fuse together at this level, and could perhaps be considered as part of the large southwestern group since they link with it at 0.49 and so only just avoid the arbitrary 0.5 similarity level to which the shading is limited (see histogram, figure 2, sites V and X). At a level of >0.5 too, the Arabian Gulf fuses with those of the northwest Arabian Sea (an "East Arabia" group), which remains separated from the main southwest or equatorial group until a very low level of similarity. Several individual sites remain separate until fairly low similarity levels; these are either remote or species poor areas; Lakshadweep and Cocos Keeling fuse with each other and with the main group at a similarity level of just over 0.4, while the Mergui Archipelago fuses with it at 0.3.

Two factors could affect this clustering pattern. Firstly, clustering could be weakened if the process of synonymising species names is incomplete, as it undoubtedly is. This is because it increases noise

in the data set which will cause an increase in apparent randomness. Secondly, it is clear also that although interesting clusters do emerge despite this, many of the sites which showed the least similarity with others are those with fewest species. The Gulf of Kutch, Cocos Keeling and Mergui sites are all apparently depauperate, and in particular the most separated grouping of all, East Arabia, is likewise composed wholly of sites with less than 53 species. This can affect the clustering because the maximum similarity which is possible between two sites with different numbers of species is always less than 1.0. For example, two sites containing 50 and 150 species have a maximum possible similarity of 0.5. Several site pairs have this disparity or greater. At one extreme, the exceptionally poor Gulf of Kutch with 14 species names will clearly be substantially separated from all other sites using any index of this type.

To overcome this, a measure was devised which would account for disparities in site richness to focus on the degree of commonality or otherwise of species. This "commonality index" was calculated for each pair of sites and is the ratio of the actual Sorensen or Dice index to the maximum possible index for that pair, or

$$I\ (\text{commonality}) = I(\text{Dice})\ /\ I(\text{max}).$$

This will show a high similarity between two sites with very different diversities if most species in the poorer one are also found in (or perhaps originate from) the richer one. The cluster analysis was rerun with this index (Figure 3).

This result shows several features in common with figure 2 but with important differences. The principal features in common are the emergence at a high fusion level (>0.7, darker shading) of: the Red Sea group (though this time including southern Oman as well); the group of central and southwestern Indian Ocean islands; and again an East Arabia group, though this time without southern Oman. This would seem to support the evidence of these groupings obtained from the first analysis. However, additional clusters involving species poor sites also emerge at this high level. Firstly, the Gulf of Kutch clusters very strongly (0.86) with southern India and Sri Lanka. Thus, the former is shown either to recruit from the latter or else have a remnant of a similar Indian mainland population. Also Lakshadweep fuses with the adjacent Maldives (0.94), and the Nicobars and Andamans fuse with the Mergui Archipelago (0.79). These clusters merge pairs of sites which are in close geographic proximity regardless of their wide differences in diversities.

At a fusion level of >0.6 (light shading), two larger groups are formed. Firstly, a broad, "equatorial" group is formed which consists of all sites from the southwest and central Indian Ocean, all atolls, and the mainland sites on both African and Asian coasts. Secondly, the East Arabia group fuses with the Red Sea group to form a northwestern grouping. Onto this, the Indian sites also fuse at a level of 0.58, to form a large group which extends between Sri Lanka and the Red Sea. At this level, the small group formed from the islands in the Bay of Bengal remains separate.

Both indexes suggest that at the higher levels of fusion there are valid groupings of higher similarity within the otherwise fairly homogeneous Indian Ocean region. Of these, the Arabian Gulf and northern Arabian Sea area is most separated. The Red Sea is also relatively distinct, while the islands between Madagascar and the central Indian Ocean atolls form a third area of higher homogeneity. Possibly the islands in the Bay of Bengal form a final group.

The principal difference between the two analyses emerges at a lower fusion level and is caused by the fusion pattern of the Red Sea: in the first case the Red Sea fuses with the southwestern or equatorial group next, leaving a separate East Arabian group. In the second treatment, which is based more on commonality of species and which overcomes bias caused by diversity difference, the Red Sea merges next with the East Arabian and Indian groups to form a broad northern or northwestern group. In the latter, the broad equatorial group thus excludes the Red Sea, but it includes the mainland sites of both Africa and Asia and all island groups between them with the exception of the islands in the Bay of Bengal.

A hypothesis of a "subprovince" in the western Indian Ocean that has high diversity has been suggested from analysis at genus level (Rosen 1971), which emerged largely from the observation that several genera were restricted to that area. However, the genera concerned were largely monospecific, e.g. *Horastrea, Gyrosmilia, Astraeosmilia, Siderastrea, Anomastrea* and possibly *Ctenella*, and most of them have subsequently been discovered in a wider range of sites which fall into several different site clusters in this analysis. Also, it would be expected that the effects of these monospecific genera would be masked by the polyspecific nature of most other genera, in particular the highly speciated Acroporidae. In fact, both the analyses performed here suggest that in the western Indian Ocean there are three areas with a greater than average degree of internal homogeneity: the Red Sea, the eastern Arabian region, and the equatorial region which includes the southwest. While at a lower level of fusion the affiliation of the Red Sea changes, the second and third of these groupings still remain separated.

The suggestion by Veron (1985a) that there is a high degree of homogeneity of corals at species level throughout the Indian Ocean is supported by this analysis, as are predictions that the Red Sea and Arabian Gulf areas support rather different assemblages of corals from the central Indian Ocean (Burchard 1979, Sheppard and Sheppard 1985). The Arabian Gulf was also separated from the more central Indian Ocean sites at generic level (Stehli and Wells 1971) although in the latter case this was forced by the depauperate nature of the known Gulf fauna, and it was grouped together with other species poor sites in the south Indian Ocean. Both the species compilation and the analysis presented here, however, should be regarded only as a first step. More work on the question of synonyms and the provision of species lists from areas not represented here, particularly the Seychelles atolls, are need to clarify the pattern in the Indian Ocean, and subsequently, to clarify their relationship to the highest diversity regions of southeast Asia.

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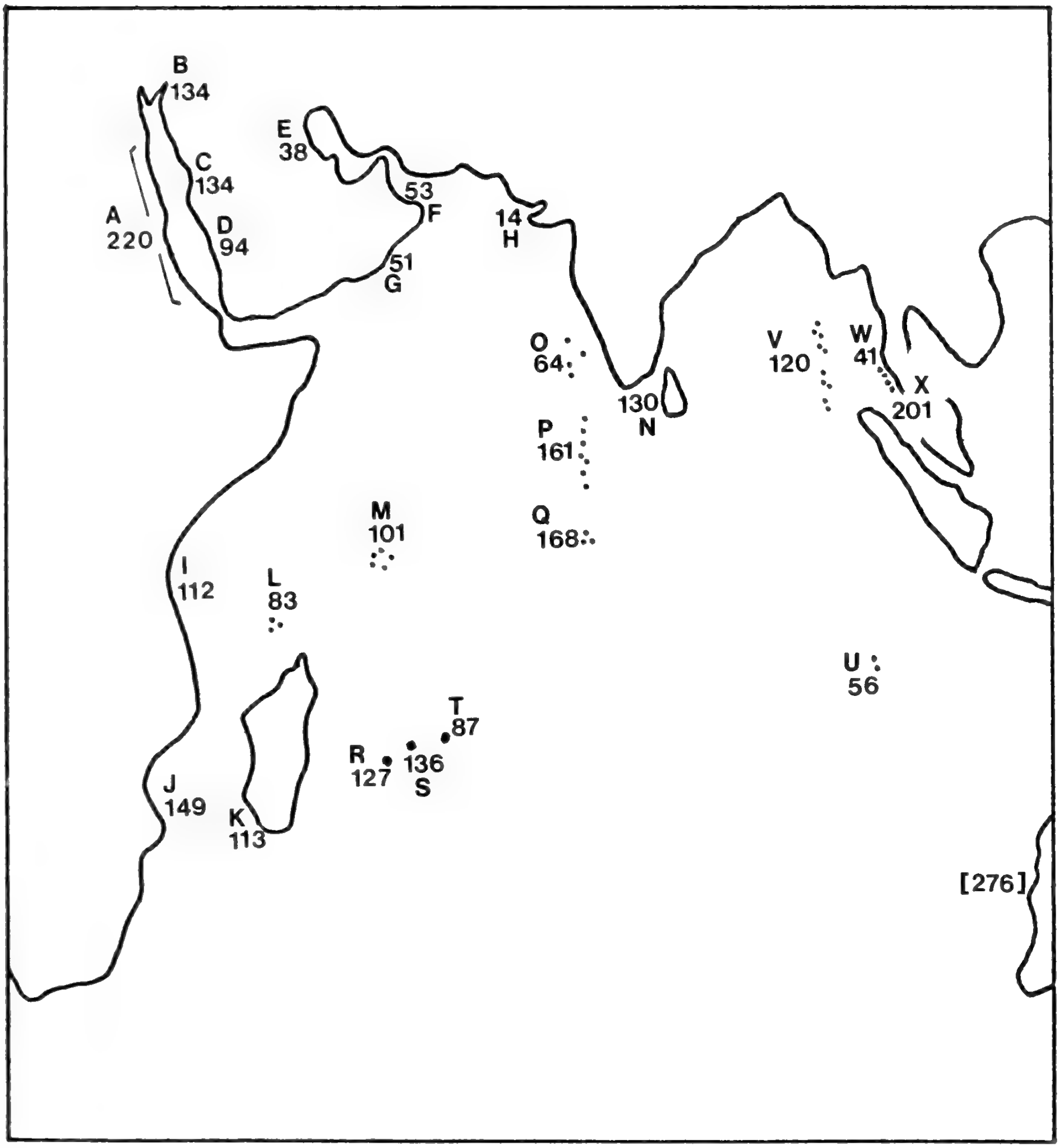
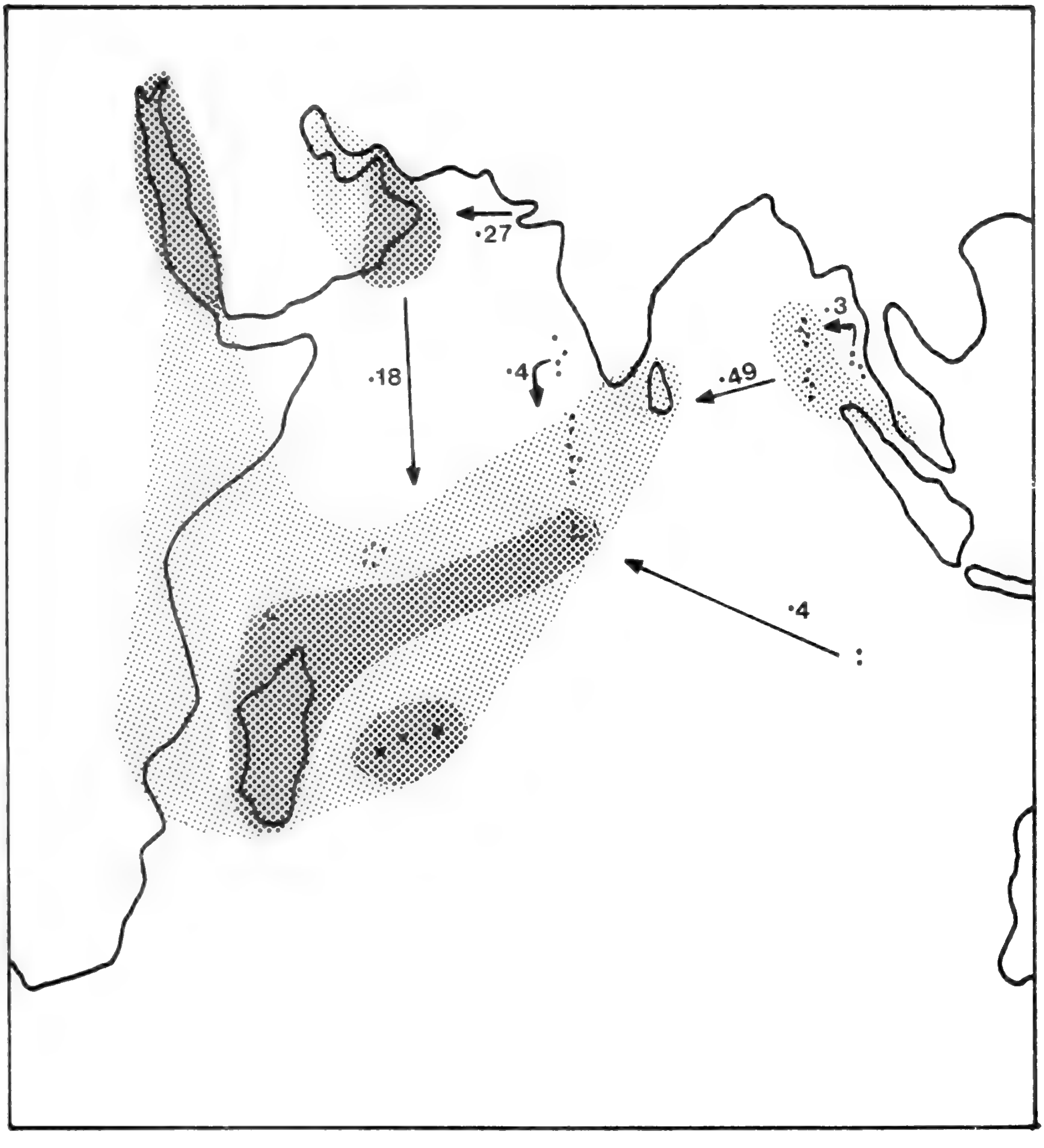
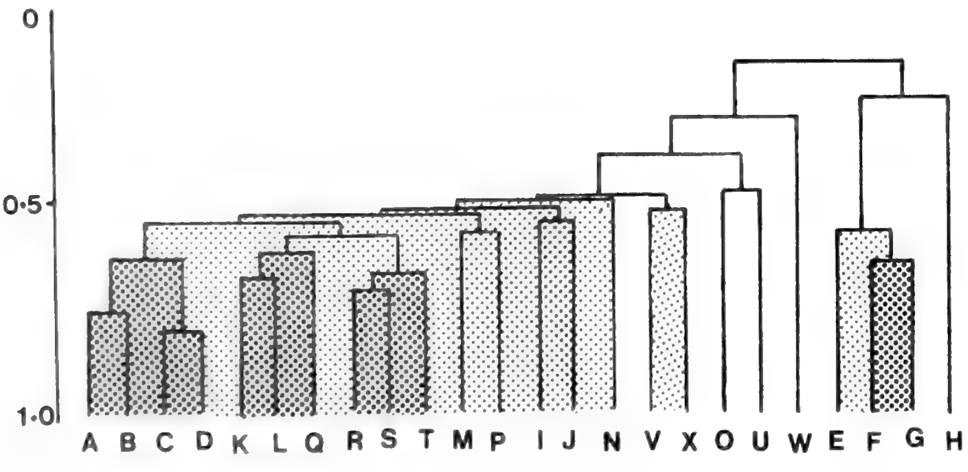


Figure 1. Map of the Indian Ocean region showing numbers of hermatypic coral species at each of the 24 sites used, based on the synonymised species list. Each site is designated by a letter, corresponding to those in Table 1. The sources used for each site are those listed in Table 1, except for western Australia whose total is stated in Veron (1985b).

Figure 2. Result of a cluster analysis using the Dice or Sorensen similarity coefficient, shown as a dendrogram (bottom) which is then mapped (top). In both cases, dark shading encloses sites which cluster at a similarity level of >0.6, light shading encloses sites clustered at >0.5. Other sites cluster at values shown by the arrows. Cocos Keeling and Lakshadweep fuse with each other marginally earlier than their fusion with the main cluster. Letters below dendrogram correspond to the site designation, as shown in Table 1.

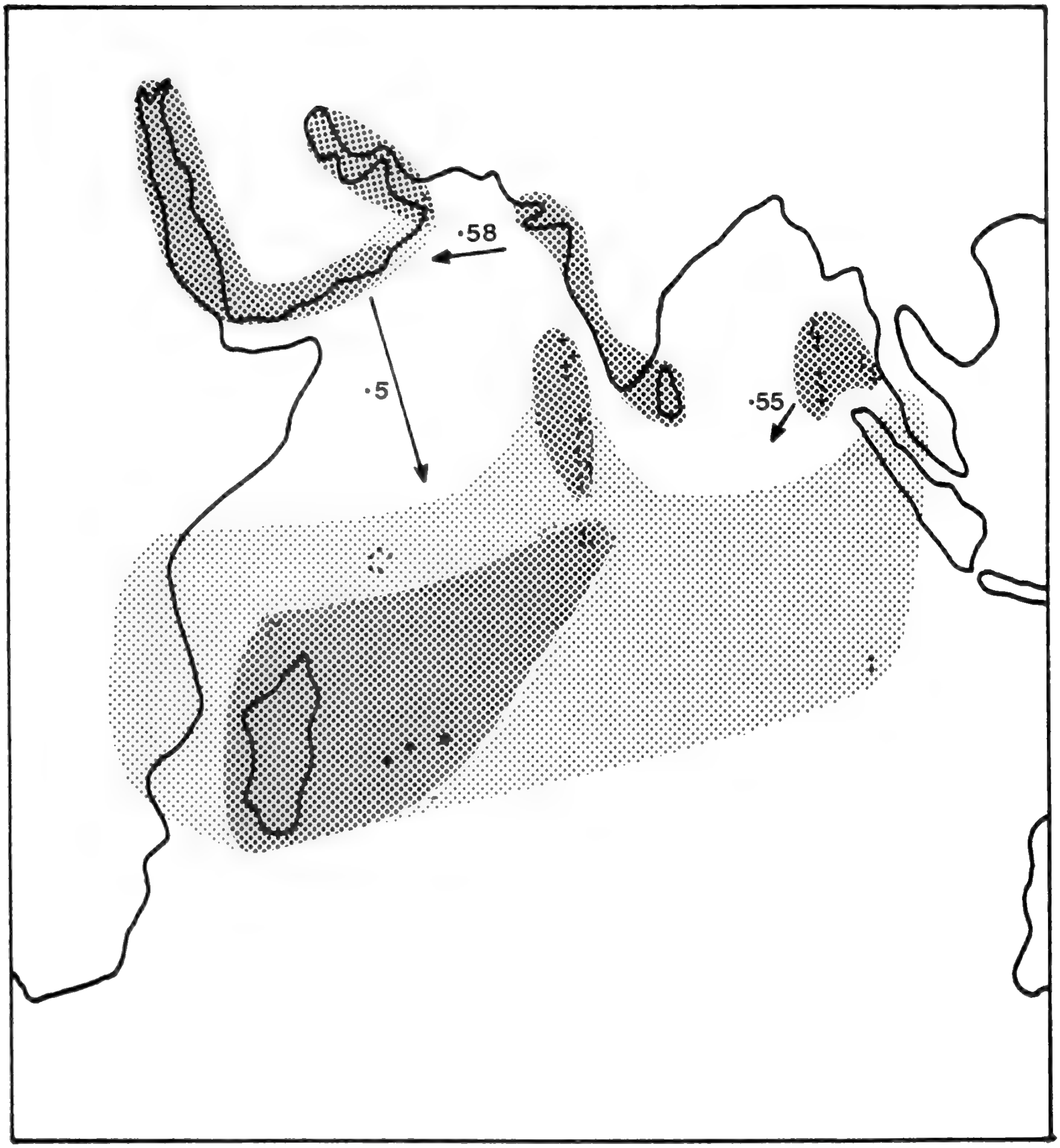


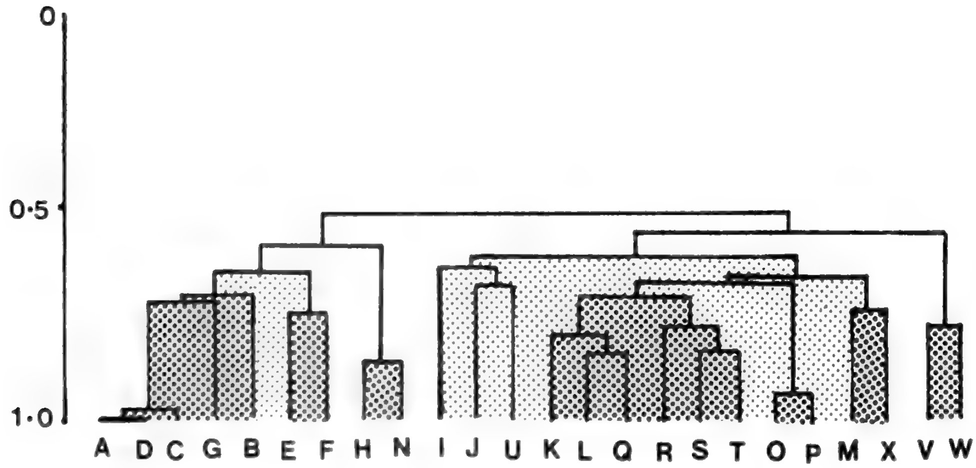
·27
·18
·4
·3
·49
·4



0
0·5
1·0
A B C D K L Q R S T M P I J N V X O U W E F G H

Figure 3. Result of a cluster analysis using the "commonality of species index" (see text), shown as a dendrogram (bottom) which is then mapped (top). Dark shading encloses sites which cluster at a similarity level of >0.7, light shading encloses sites clustered at >0.6. (NB Seychelles and Thailand cluster at 0.74, shown on dendrogram but not on map for clarity). Other sites or groups fuse with larger ones at values shown by the arrows. Letters below dendrogram correspond to the site designation, as shown in Table 1.


·58
·5
·55


0
0·5
1·0
A D C G B E F H N I J U K L Q R S T O P M X V W

APPENDIX 1. List of coral species recorded from the Indian Ocean; sources are given in Table 1. In the columns on the right, sites are ordered left to right as in Table 1, eg column 1= Red Sea, column 24= Thailand. A "1" means the species has been recorded there by the authors cited in Table 1. A dot is placed in each vacant cell to facilitate tracing. Junior or redundant synonyms are indented beneath the species name considered to be the senior or valid synonym.

```
Stylocoeniella armata (Ehrenberg)             1.......1.......111.1...
Stylocoeniella guentheri  Basset-Smith        1.11.1....1.1..111.....1

Psammocora contigua  (Esper)                  1...11..111.11111111...1
  Psammocora divericata Gardiner              ...............1........
  Psammocora gonagra Klunzinger               .........1..............
  Psammocora planipora Edwards & Haime        ..................1.....
  Psammocora vaughani Yabe & Sugiyama         ..................1.....
Psammocora brighami  (Vaughan)                .........1..............
Psammocora digitata Edwards & Haime           ...............1.......1
  Psammocora exesa Dana                       ..............11........
  Psammocora togianensis Umbgrove             ............1..1....1...
Psammocora explanulata Horst                  1.11............11......
Psammocora folium Umbgrove                    ...............1..1.....
Psammocora haimeana Edwards & Haime           111......111..11.11.1...
Psammocora nierstrazi Horst                   111.....1.11...1111.....
Psammocora profundicella Gardiner             1.1.............111..1.1
Psammocora ?superficialis  Gardiner           1.1.11..................

Stylophora contorta  Ley.                     .........1..............
Stylophora flagelalta (Quelch)                .........1..............
Stylophora pistillata  Esper                  1111111.11111..11111...1
  Stylophora danae Edwards & Haime            1........1..............
  Stylophora mordax (Dana)                    ..........111.11.111.1..
  Stylophora palmata Blainville               .1.......1..............
  Stylophora prostrata Klunzinger             .1......................
  Stylophora septata Gardiner                 ........1...............
  Stylophora subseriata (Ehrenberg)           1........11....1..1.....
Stylophora welsii Scheer                      1111....................
Stylophora kuehlmanni Scheer & Pillai         1.......................
Stylophora mamillata Scheer & Pillai          1.......................

Seriatopora caliendrum  Ehrenberg             1111..1.....1.....1....1
Seriatopora crassa Quelch                     .....................1..
Seriatopora hystrix Dana                      1.11....1111....1.1..1.1
  Seriatopora angulata Klunzinger             .1.......1..1..1..1.1...
Seriatopora spinosa Edwards & Haime           11......................
Seriatopora stellata Quelch                   ..................1..1..
Seriatopora stricta Brueggemann               ................1.......
Seriatopora octoptera Ehrenberg               1.......................

Pocillopora ankeli Scheer & Pillai            .....................1..
Pocillopora clavaria Ehrenberg                .........1..............
```

Pocillopora damicornis Linnaeus	111111..11111111111111.1
Pocillopora acuta Lamarck	...............1........
Pocillopora brevicornis (Lamarck)	..........1..1...11111..
Pocillopora bulbosa Ehrenberg	.........11.............
Pocillopora cespitosa Dana	.........1.......111....
Pocillopora favosa Ehrenberg	.........1.........1..1.
Pocillopora eydouxi Edwards & Haime	........1.11111111.111.1
Pocillopora grandis Dana	.........1.......111....
Pocillopora informis Dana	.........1...1..........
Pocillopora ligulata Dana	.........1....11........
Pocillopora mauritiana Brueggemann	..................1.....
Pocillopora meandrina Dana	...............1.....1.1
Pocillopora molokensis (Ellis & Solander)	.............1.1........
Pocillopora verrucosa Ellis & Solander	1.11..1.111.1.11111111.1
Pocillopora danae Verrill	.1........11.1.1.111....
Pocillopora elegans Dana	..........1..1....1.1...
Pocillopora hemprichi Ehrenberg	11......................
Pocillopora woodjonesi Vaughan	....................1...
Madracis kirbyi Veron & Pichon	....11..........1......1
Acropora aculeus (Dana)	........1..............1
Acropora elegantula (Ortmann)	.............1..........
Acropora acuminata (Verrill)	1
Acropora alces Brueggemann	...................1....
Acropora anthoceris (Brook)	.........1..............
Acropora appressa (Ehrenberg)	..................1.....
Acropora aspera (Dana)	................1......1
Acropora cribripora (Dana)	......................1.
Acropora hebes (Dana)	....................111.
Acropora attenuata (Brook)	................1.......
Acropora austera (Dana)	1.11...................1
Acropora brueggemanni (Brook)	........11..1...........
Acropora bushyensis=turbicinaria(Dana)	...........1............
Acropora carduus (Dana)	1
Acropora capillaris (Klunzinger)	11......................
Acropora cerealis (Dana)	............1....11....1
Acropora hystrix (Dana)	...............1........
Acropora tizardi (Brook)	.........1..............
Acropora ceylonica (Ortmann)	.............1..........
Acropora cervicornis (Lamarck)	.........1...1..........
Acropora clathrata (Brook)	1.11..1.1.......111....1
Acropora complanata (Brook)	.........1..1...........
Acropora orbicularis (Brook)	.............1..........
Acropora vasiformis (Brook)	.........1.....1........
Acropora corymbosa (Lamarck)	11.......11.1111.1111...
Acropora cuneata (Dana)	........1..1............
Acropora cytherea (Dana)	1.11....1...1....1.....1
Acropora arcuata (Brook)	.........1..............
Acropora efflorescens (Dana)	.............111.....1..
Acropora symmetrica? (Brook)	.........1........1.....
Acropora reticulata (Brook)	..........1.1.111111....

Acropora danai (Edwards & Haime)	1.11......1.1....111...1
Acropora abrotanoides (Lamarck)	..............111.......
Acropora irregularis (Brook)	........11.1...1..1.1...
Acropora rotumana (Gardiner)	........1.1....1........
Acropora dendrum Bassett-Smith	1
Acropora digitifera (Dana)	1.11......11.1.1.1.....1
Acropora baeodactyla (Brook)	.........1........11....
Acropora brevicollis Brook	...................1....
Acropora effusa (Dana)	.............1..........
Acropora leptocyathus (Brook)	.........1..............
Acropora divericata (Dana)	1
Acropora complanata (Brook)	...............1........
Acropora donei Veron & Pichon	1
Acropora dumosa Brook)	.....................1..
Acropora echinata (Dana)	..........1...11.......1
Acropora procumbens (Brook)	.....................1..
Acropora effluens (Dana)	...............1........
Acropora elseyi (Brook)	...............1........
Acropora exilis (Brook)	.........1..............
Acropora eurystoma (Klunzinger)	11..........1..11.......
Acropora flabelliformis Edwards & Haime	...................1....
Acropora florida (Dana)	........1..............1
Acropora gravida (Dana)	.........1........1..1..
Acropora formosa (Dana)	1.11....1....1111...11.1
Acropora arbuscula (Dana)	..........1.....1.11.1..
Acropora exigua? (Dana)	.............1..........
Acropora multiformis (Ortmann)	.............1..........
Acropora virgata (Dana)	.....................1..
Acropora forskalii (Ehrenberg)	1.......1.....11........
Acropora gemmifera (Brook)	1
Acropora glochiclados (Brook)	...........1....1.......
Acropora gonagra (Edwards & Haime)	..................11....
Acropora grandis (Brook)	1.11..............1....1
Acropora granulosa (Edwards & Haime)	11..........1....1......
Acropora eibli Pillai & Scheer	...............1........
Acropora massawensis Marenzeller	........1...............
Acropora hemprichi (Ehrenberg)	11......1....111.111....
Acropora horrida (Dana)	1
Acropora tylostoma Ehrenberg	..................1.....
Acropora humilis (Dana)	1111....1.1.11111111.1.1
Acropora calamaria (Brook)	.................1......
Acropora erythraea (Klunzinger)	.........1...1.1..1.....
Acropora obscura (Brook)	.............1..........
Acropora ocelata (Klunzinger)	........11..........1...
Acropora paxilligera (Dana)	......................1.
Acropora pyrimidalis (Klunzinger)	..................1.....
Acropora scherzeriana Brueggemann	..................1.1...
Acropora seriata (Ehrenberg)	.............1....11..1.
Acropora spectabilis (Brook)	.........1..............

Acropora hyacinthus (Dana)	1111....111.11111111.1.1
Acropora conferta (Brook)	..............1...11....
Acropora pectinia (Brook)	.........1..............
Acropora recumbens (Brook)	........11..............
Acropora spicifera (Dana)	........11.111......1...
Acropora surculosa (Dana)	.............1.1.1....1.
Acropora indica (Brook)	.........1...11.........
Acropora latistella (Brook)	1
Acropora patula (Brook)	.........1..............
Acropora listeri (Brook)	1
Acropora loripes (Brook)	.1.......1.............1
Acropora murrayensis Vaughan	................1.......
Acropora squarrosa (Ehrenberg)	1.............11........
Acropora longicyathus (Edwards & Haime)	.........1......1......1
Acropora rosaria (Brook)	............1...........
Acropora lovelli Veron & Wallace	1
Acropora lutkeni Crossland	1
Acropora microphthalma (Verrill)	1
Acropora monticulosa (Brueggamann)	...........1..1........1
Acropora multiacuta Nemenzo	.....................1..
Acropora muricata (Lamarck)	..................1.....
Acropora nana (Studer)	....................1...
Acropora nasuta (Dana)	1111.....1.............1
Acropora cymbicyathus (Brook)	................1.......
Acropora disticha Brook	................1.......
Acropora quelchi (Brook)	...............1........
Acropora nobilis (Dana)	1.11.........1.......1.1
Acropora intermedia (Brook)	........11...111........
Acropora oligocyathus (Brook)	..................1.....
Acropora palifera (Lamarck)	........1111..111...11..
Acropora pharaonis Edwards & Haime	1....11.1.1.1111.1111...
Acropora pustulosa (Edwards & Haime)	...................1....
Acropora scandens (Klunzinger)	.1......................
Acropora polymorpha (Brook)	.........1..11..........
Acropora polystoma (Brook)	1.1......1.......11.....
Acropora pruinosa (Brook)	.....................1..
Acropora pulchra (Brook)	.........1.......1..1..1
Acropora rambleri Bassett-Smith	.........1....1......1..
Acropora robusta (Dana)	1..1...................1
Acropora conigera (Dana)	........1......1........
Acropora decipiens Brook	.........11.............
Acropora palmerae Wells	.................1.....1
Acropora pinguis Wells	..........1.........11..
Acropora smithi (Brook)	.....................1..
Acropora samoensis (Brook)	1
Acropora schmitti Wells	....................1...
Acropora secale (Studer)	1.1.....1....1.......1.1
Acropora diversa (Brook)	........11.1.1..1....1..
Acropora plantaginea (Lamarck)	.............1.....1....
Acropora selago (Studer)	.............1.........1
Acropora deliculata (Brook)	.........1..............
Acropora stigataria Edwards & Haime	..................1.....
Acropora stoddarti Scheer & Pillai	1.11...........1........

Acropora subglabra (Brook)	1
Acropora syringoides (Brook)	...............1.111.1..
Acropora tenuis (Dana)	........1..............1
Acropora africana (Brook)	.........1...1..........
Acropora kenti (Brook)	..................1.....
Acropora macrostoma (Brook)	.........1........1.....
Acropora teres Verrill	...............1........
Acropora thurstoni (Brook)	.............1..........
Acropora tuburculosa Edwards & Haime	..................1.....
Acropora valenciennesi (Edwards & Haime)	1....11......1..........
Acropora multicaulis (Brook)	.............1....1.....
Acropora valida (Dana)	1.11.11......1.1.1....11
Acropora concinna (Brook)	.........1.....1..1.....
Acropora rousseauii Edwards & Haime	........1.........1.....
Acropora variabilis (Klunzinger)	11......1..11..111..11..
Acropora vaughani Wells	1.1....................1
Acropora verweyi Veron & Wallace	1
Acropora yongei Veron & Wallace	1111....................
Acropora haimei Edwards & Haime	1............1111.11....
Montipora aequituberculata Bernard	.....11................1
Montipora composita Crossland	.1...........1.......1..
Montipora erythraea Marenzeller	.1......1..1....11......
Montipora verrilli Vaughan	1........1...1..........
Montipora alveopora Bernard	.............1..........
Montipora angulata (Lamarck)	1
Montipora cocosensis Vaughan	....................11..
Montipora circumvallata (Ehrenberg)	11...............1......
Montipora abrotanoides (Audouin)	....1...................
Montipora crassituberculata Bernard	1
Montipora culiculata Bernard	................1.......
Montipora danae Edwards & Haime	1111...........1........
Montipora brueggemanni Bernard	................1.......
Montipora meandrina (Ehrenberg)	11.......1..............
Montipora rus (Forskal)	..................1.....
Montipora tuberculata? (Lamarck)	.............1..........
Montipora digitata (Dana)	.............1......11.1
Montipora divericata Brueggemann	.............1.....1....
Montipora levis Quelch	....................1...
Montipora ramosa Bernard	........1...........1...
Montipora tortuosa (Dana)	....................1...
Montipora edwardsi Bernard	1.........1.11..11.1....
Montipora cf efflorescens Bernard	.....1..................
Montipora effusa (Dana)	1........1...1..........
Montipora ehrenbergi Verrill	11......................
Montipora elscheri Vaughan	...........1.1..........
Montipora explanata Brueggemann	.............1....11....
Montipora explanulata Bernard	................1.......
Montipora exserta (Quelch)	.............1..........
Montipora flabellata Studer	.........1..............
Montipora floweri Wells	1.11...........1........

Montipora foliosa Pallas	........111..1.1.11111..
Montipora prolifera Brueggemann	............1..1........
Montipora pulcherrima Bernard	...............1........
Montipora foveolata Bernard	................1......1
Montipora socialis Bernard	........11..............
Montipora friabilis Bernard	.........1..............
Montipora gracilis Klunzinger	1.......................
Montipora granulosa (Bernard)	1............1..........
Montipora hispida (Dana)	................1......1
Montipora expansa Dana	..................1.1...
Montipora patula Verrill	.........1..............
Montipora punctata Bernard	...........1............
Montipora informis Bernard	..........1.11.1.1..11..
Montipora granulata Bernard	11......................
Montipora lichen Dana	...................1....
Montipora maldivensis Pillai & Scheer	...............1........
Montipora manauliensis Pillai	.............1..........
Montipora millepora Crossland	..................1.....
Montipora subtilis? Bernard	.............1...1......
Montipora monasteriata (Forskal)	11...1.......1.........1
Montipora fungiformis Bernard	.........1..............
Montipora incrustans Brueggemann	...................1....
Montipora languinosa Bernard	..................1.....
Montipora verrucosa (Lamarck)	11......111111..111....1
Montipora mollis Bernard	1.1....................1
Montipora paupera Mamen.	.........1..............
Montipora peltiformis Bernard	.....................1.1
Montipora perforata Bernard	...................1....
Montipora sinuosa Pillai & Scheer	...............1........
Montipora spongiosa (Ehrenberg)	11...........1..........
Montipora spongodes Bernard	............1..........1
Montipora spumosa (Lamarck)	1........1...1......1..1
Montipora guppyi Bernard	..................1.....
Montipora lobulata Bernard	11..1...........1.1.1...
Montipora stellata Bernard	1.11.11.........1.......
Montipora solanderi? Bernard	.................111....
Montipora stylosa (Ehrenberg)	11................1.....
Montipora suvadivae Pillai & Scheer	...............1........
Montipora tenuissima Bernard	................1.......
Montipora tuberculosa (Lamarck)	11.......1.111..1111....
Montipora mammifera Bernard	..................1.....
Montipora sinensis Bernard	...............1........
Montipora turgescens Bernard	.............1.......1..
Montipora undata Bernard	..................1.....
Montipora venosa (Ehrenberg)	11....11.....1...1...1..
Anacropora forbesi Ridley	....................1...
Astreopora expansa Brueggemann	................1.......
Astreopora gracilis	...............1........
Astreopora listeri Bernard	.........11.1..11....1..
Astreopora horizontalis Bernard	........1........1......
Astreopora mortonensis Veron & Wallace	1

Astreopora myriophthalma (Lamarck)	111..1..11.1.1.111111..1
Astreopora incrustans?	...............1.1......
Astreopora profunda Verrill	........1.......1.......
Astreopora ocellata Bernard	...............111......
Pavona acuticarinata (Umbgrove)	...............1........
Pavona cactus (Forskal)	111111...11.1...11111..1
Pavona danai	.........11.1....1.11...
Pavona praetorta (Dana)	....1....1.1......1..1..
Pavona venusta (Dana)	....1...................
Pavona clavus (Dana)	11.......11.1..11111.1.1
Pavona duerdeni (part) Vaughan	.............111........
Pavona clivosa Verrill	.........1.1...1........
Pavona decussata (Dana)	1111....1.1..1...11.1..1
Pavona crassa (Dana)	......................1.
Pavona lata Dana	...................1111.
Pavona seriata Brueggemann	..................1.....
Pavona diffluens (Lamarck)	....1...................
Pavona divericata Lamarck	11......111..1...111....
Pavona duerdeni (part) Sheer & Pillai	1.11.....1.....1.....1..
Pavona cf. explanulata (Lamarck)	1111111..11111.11111.1.1
Pavona frondifera Lamarck	........1.11....111.....
Pavona maldivensis (Gardiner)	1111....1..1111111..11.1
Pavona pollicata Wells	...............1.1......
Pavona minor Brueggemann	...........1............
Pavona minuta Wells	......1................1
Pavona varians (Verrill)	11111...11111111111111.1
Pavona venosa (Ehrenberg)	1.1...1................1
Pavona obtusata (Quelch)	........1.......11......
Pavona xarifae Scheer & Pillai	.....................1..
Gardineroseris planulata (Dana)	1.11..1.1..1...111.....1
Gardineroseris ponderosa (Gardiner)	.....................1..
Agariciella minikoiensis (Gardiner)	........1...............
Agaricia ponderosa Gardiner	.1.......11......111....
Pavona planulata (Dana)	...............1........
Pavona ponderosa (Gardiner)	...............1........
Coeloseris mayeri Vaughan	........1............1.1
Pachyseris rugosa (Lamarck)	11........11.1..11...1.1
Pachyseris valenciennesi Ed. & Haime	.1...........1.1........
Pachyseris speciosa (Dana)	1111....111.1..11111.111
Pachyseris levicollis (Dana)	...........1...11.1..1..
Leptoseris explanata Yabe & Sugiyama	11.....................1
Leptoseris fragilis Edwards & Haime	11.............1.1...1..
Leptoseris gardineri Horst	1..............1.......1
Pavona gardineri (Horst)	11.........1...1........
Leptoseris hawaiiensis Vaughan	1.11.....11.1...111..1.1
Leptoseris tubulifera Vaughan	.1.........1............
Leptoseris incrustans (Quelch)	.........11....11111....
Leptoseris mycetoseroides Wells	1111.1...111....111....1

Leptoseris papyracea (Dana)	..........1.1........1.1
Leptoseris digitata Vaughan	.........1........1.....
Leptoseris scabra Vaughan	1.11......1....111.....1
Leptoseris columna Yabe & Sugiyama	...........1.....1......
Leptoseris regularis (Quelch)	.........1..............
Leptoseris solida	..........1.............
Leptoseris porosa (Quelch)	.........1..............
Leptoseris tenuis Horst	1.1..1..................
Leptoseris foliosa Dinesen	................1......1
Leptoseris yabei (Pillai & Scheer)	1.11....................
Pavona yabei Pillai & Scheer	11.............1........
Siderastrea savignyana Edwards & Haime	1.11111.....11.......1..
Siderastrea lilacea	.1.....1.....1........1.
?Siderastrea radians (Pallas)	.........11..1..........
?Siderastrea siderea Ellis & Solander	.........1..............
Pseudosiderastrea tayamai Yabe & Sug.	....111...1.............1
Anomastrea irregularis Marenzeller	....111.11..............
Coscinaraea columna (Dana)	......1..1111...11.1...1
Coscinaraea monile (Forskal)	111111111111.1.11111..11
Coscinaraea donnani Gardiner	.........1......1.......
Coscinaraea ostraeformis Horst	................1.......
Coscinaraea wellsi Veron & Pichon	................1......1
Craterastrea levis Head	1...............1.......
Horastrea indica Pichon	.........11......11.....
Cycloseris cooperi (Gardiner)	...............1........
Cycloseris costulata Ortmann	11.......1..11.11......1
Cycloseris cyclolites (Lamarck)	1.........11.1...111.1.1
Cycloseris doederleini (Marenzeller)	11......................
Cycloseris erosa Doederlein	11.......1..............
Cycloseris hexagonalis Edwards & Haime	.............1.......1..
Cycloseris marginata (Boschma)	................1....1.1
Cycloseris mycoides Alcock	.....................1..
Cycloseris patelliformis (Boschma)	11......1...1....1...1..
Cycloseris somervillei (Gardiner)	..........1...1.1.1..11.
?Cycloseris sinensis Edwards & Haime	...............1........
Cycloseris tenuis Dana	................1.......
Cycloseris vaughani (Boschma)	1.11.............1......
Diaseris distorta (Michelin)	11......1111.1.11....1.1
Diaseris fragilis Alcock	.........1...........1..
Heliofungia actiniformis (Quoy & Gaimard)	.........1..............

Fungia (Fungia) fungites (Linnaeus)	1111....11111.11111111.1
Fungia agariciformis Lamarck	..................1.....
Fungia haimei Verrill	...................1....
Fungia patella (Ellis & Solander)	..................1.....
Fungia (Danafungia) corona Doderlein	1.1............1....11.
Fungia (Danafungia) danai Edwards & Haime	1.........1.11111111.1..
Fungia (Danafungia) horrida Dana	111......11.....1....1..
Fungia (Danafungia) klunzingeri Doderlein	111.....................
Fungia (Danafungia) scruposa Klunzinger	11..............1.......
Fungia (Danafungia) subrepanda Doderlein	....................1..
Fungia (Danafungia) valida Verrill	1.1......1......1.....1
Fungia (Danafungia) madagascarensis Ver.	..................1.....
Fungia (Ctenactis) echinata (Pallas)	11...........1.1.....111
Fungia (Verrillofungia) concinna Verrill	1........1......1....1.1
Fungia (Verrillofungia) plana (Studer)	........1...............
Fungia (Verrillofungia) fieldi Gardiner	................1.......
Fungia (Verrillofungia) granulosa Klunz.	111.............1......1
Fungia (Verrillofungia) repanda (Dana)	1.......1.1.11.11......1
Fungia (Verrillofungia) samboangensis V.	..................1.....
Fungia (Pleuractis) moluccensis Horst	11.....................1
Fungia (Pleuractis) paumotensis Stuchbury	1.1.......11.....1...1.1
Fungia (Pleuractis) scutaria Lamarck	1111....11111111111.11.1
Fungia dentigera Leuckart	...................1....
Herpetoglossa simplex (Gardiner)	1.11...........11....1.1
Herpolitha limax (Hottuyn)	1111....111111.111111111
Herpolitha weberi (Horst)	...............1.......1
Halomitra pileus (Linnaeus)	............1...1......1
Halomitra philippinensis Studer	........1.1....1........
Polyphyllia talpina (Lamarck)	...............11....111
Podabacia crustacea (Pallas)	1111....1111.111111....1
Sandalolitha robusta Quelch	.............1.1.......1
Sandalolitha dentata Quelch	...............1........
Lithophyllon edwardsi (Rousseau)	1
Porites australensis Vaughan	........1.......1.......
Porites fragosa (Dana)	.............1..........
Porites cocosensis Wells	........1...........1...
Porites columnaris Klunzinger	1.................1.....
Porites compressa Dana	1...1..1.1...1..........
Porites cribripora Dana	.............1..........
Porites cylindrica Dana	1
Porites andrewsi Vaughan	1.......11111.111.1.....
Porites levis Dana	....................1...
Porites echinulata Klunzinger	11...........1..........
Porites exserta Pillai	.............1..........
Porites faustinoi Hoffmeister	........1.......1.......

Porites gaimardi Edwards & Haime	.............1..........
Porites gibsonhilli Wells	....................1...
Porites lichen Dana	1.11......11.1.11.1.1...
Porites viridis Gardiner	.........1..............
Porites lobata Dana	1.1.....11..1.....1..1.1
Porites lutea Edwards & Haime	1111111.11.111111111.1.1
Porites arenosa (Esper)	.........1.......1.1....
Porites somaliensis Gravier	........1.1..11.11111...
Porites mannarensis (Pillai)	.............1..........
Porites mauritiensis Bernard	...............1..1.....
Porites mayeri Vaughan	11......................
Porites minicoyensis Pillai	..............1.........
Porites mordax Dana	........1...............
Porites murrayensis Vaughan	....1...1......1.....1.1
Porites nigrescens Dana	1.11..1.11111...111.1..1
Porites suppressa Crossland	.....................1..
Porites nodifera Klunzinger	1...1.1......1..........
Porites nodulosa Verrill	.........1..............
Porites palmata Dana	..............11........
Porites profundus Rehberg	...............1........
Porites pukoensis Vaughan	..........1......1.1....
Porites punctata (Klunzinger)	1.........11.1..........
Porites seychelles 1 Barnard	........1...............
Porites solida (Forskal)	1....11..11..111111111..
Porites alveolata Edwards & Haime	.1...........1.1........
Porites stephensoni Crossland	1.1....................1
Porites studeri Vaughan	11......................
Porites thurstoni Pillai	.............1..........
Porites vaughani Crossland	1
Porites (S) rus (Forskal)	1.11...................1
Porites (S) iwayamaensis Eguchi	1.........11....1111....
Porites (S) convexa Verrill	........1....1.1........
Porites (S) danai Ellis & Solander	............1....111....
Porites (S) monticulosa (Dana)	...............1........
Porites (S) undulata	11..........1...........
Porites (N) horizontalata Hoffmeister	...............11.......
Porites n. sp.Loya & Slobodkin	11......................
Goniopora djiboutiensis Vaughan	.....1.......1.........1
Goniopora pulvinula Wells	...............1........
Goniopora fruiticosa Saville-Kent	1
Goniopora gracilis (Edwards & Haime)	.................1......
Goniopora granulosa Pillai & Sheer	...............1........
Goniopora cf. klunzingeri Marenzeller	11...1..................
Goniopora lichen (Dana)	11......................
Goniopora lobata Edwards & Haime	1.11.1......11...111...1
Goniopora mauritiensis Bernard	.................11.....
Goniopora minor Crossland	11..........1.111......1
Goniopora pandoraensis Veron & Pichon	1
Goniopora parvistella Ortman	.........1..............
Goniopora planulata (Ehrenberg)	11.............1........
Goniopora columna Dana	111
Goniopora duofaciata Thiel	............11.1........

Goniopora reptans Bernard	................1.......
Goniopora savignyi (Dana)	11.......1..1...111.....
Goniopora somaliensis Vaughan	1...........11...1......
Goniopora stokesi Edwards & Haime	11........1111111....1.1
Goniopora stutchbury Wells	1
Goniopora nigra ?Pillai	.......1.....1..........
Goniopora tenella (Quelch)	11......................
Goniopora tenuidens Quelch	1....11.........111..1.1
Goniopora viridis Quoy & Gaimard	.........1..............
Goniopora Ceylon 1 Bernard	................1.......
Alveopora allingi Hoffmeister	...............11......1
Alveopora mortenseni Crossland	11......1......1.111....
Alveopora daedalea (Forskal)	11.......1.....1..1.....
Alveopora fenestrata Lamarck	............1....1......
Alveopora ocellata Wells	11......................
Alveopora octoformis Blainville	..................1.....
Alveopora retipora Blainville	..................1.....
Alveopora simplex	................1.......
Alveopora spongiosa Dana	1.1....................1
Alveopora superficialis Pillai & Scheer	1..............1........
Alveopora tizardi Bassett-Smith	1.1.....................
Alveopora verrilliana Dana	11......................
Alveopora viridis (Quoy & Gaimard)	11.......1...1.1........
Caulastrea furcata Dana	........1...1..1........
Caulastrea tumida Matthai	11......111....1111.....
Erythrastrea flabellata Pichon et al	11......................
Cladocora arbuscula (Lessueur)	.........1..............
Astraeosmilia connata Ortmann	........1...............
Astraeosmilia sp.	................1.......
Barabattoia amicorum (Edwards & Haime)	11.......1..1...1......1
Favia favus (Forskal)	11111.1..111.1111111.1.1
Favia danae Verrill	.............1..........
Favites ehrenbergi (Klunzinger)	..............11........
Favia fragum (Esper)	.........1..............
Favia helianthoides Wells	1.1....................1
Favia laxa (Klunzinger)	1.1.....11.......1.....1
Goniastrea laxa Quelch	.........1..............
Plesiastrea laxa (Klunzinger)	.1......................
Favia ?lizardensis Veron et al	..1....................1
Favia maritima (Nemenzo)	........1...............
Favia matthai Vaughan	1.1.............11.....1
Favia maxima Veron et al	................1......1
Favia pallida (Dana)	1.111111111111111111.1.1
Favia doreyensis Edwards & Haime	.1......................
Favia huluensis Gardiner	...............1........
Favia rotumana (Gardiner)	1.1......1.....1.1...1.1

Favia speciosa (Dana)	1111111.11...11111111111
Favia stelligera (Dana)	1111.....11111.1111111.1
Favia hombroni (Rousseau)	.................111....
Goniastrea hombroni Rousseau	..............111....1..
Favia valenciennesi (Edwards & Haime)	.............1.1.....11.
Favia wisseli Scheer & Pichon	1.......................
Favites abdita Ellis & Solander	1111..1..111.11111111111
Favites virens (Dana)	.1.......11111.1.111....
Favites bennettae Veron et al	1
Favites chinensis (Verrill)	1.11111.11......1.......
Favites auticollis (Ortmann)	11...........1..........
?Favites melicerum (Ehrenberg)	.............111....1.1.
Favites complanata (Ehrenberg)	111......1..11.1.1......
Favites hemprichi (Ehrenberg)	...............1........
Favites flexuosa (Dana)	1111........1..111...1.1
Favites halicora (Ehrenberg)	1111...1.11..1111....1..
Favites pentagona (Esper)	1111111.111111111111..11
Favites peresi Faure & Pichon	1111..1.........11......
Favites rotundata Veron et al	111.....................
Prionastrea rodericana Brueggemann	...................1....
Prionastrea scabra Brueggemann	...................1....
Goniastrea aspera Verrill	1
Favites aspera Verrill	................1.......
Favites spectabilis (Verrill)	.........1..............
Goniastrea incrustans Duncan	.............1...111..1.
Goniastrea australensis (Edwards & Haime)	1.1.....11..............
Goniastrea seychellensis Ed. & Haime	1...........1...1.......
Goniastrea edwardsi Chevalier	1.11.....1..1...1......1
Goniastrea paulauensis (Yabe et al)	...........1....11.....1
Goniastrea pectinata (Ehrenberg)	1111...1..1111.11111.1.1
Goniastrea retiformis (Lamarck)	111....1111111111111.111
Goniastrea hombroni (cf Scheer)	1....................1..
Platygyra daedalea (Ellis & Solander)	1.11111111111...1111...1
Platygyra astreiformis (Ed. & Haime)	...........1............
Platygyra rustica (Dana)	.1......................
Platygyra lamellina (Ehrenberg)	1111..1.111111111111.11.
Platygyra subdentata Edwards & Haime	.1......................
Platygyra pini Chevalier	1
Platygyra crosslandi? (Matthai)	11......................
Playtgyra sinensis (Edwards & Haime)	1...11..........1......1
Platygyra ryukyuensis (Yabe & Sugiyama)	.............1..........
Favia sinensis (Edwards & Haime)	........1...............
Platygyra verweyi Wijsman Best	1
Leptoria phrygia Ellis & Solander	1111..1.11111111111111.1
Oulophyllia crispa (Lamarck)	1.11....111.1..11111...1
Oulophyllia aspera Quelch	.........1.....1..1..1..
Montastrea annuligera (Edwards & Haime)	.........1..1....1......

Montastrea aperta (Verrill)	.........1..............
Montastrea curta (Dana)	1.11......1.....111....1
Montastrea magnistellata Chevalier	1.1.........1..........1
Montastrea valenciennesi Edwards & Haime	................1......1
Oulastrea crispata Lamarck	.....................1.1
Plesiastrea versipora (Lamarck)	1.11111...111111111111.1
Plesiastrea mammillosa (Klunzinger)	.1......................
Plesiastrea urveilli Edwards & Haime	..........1.............
Diploastrea heliopora (Lamarck)	1.11......111.111....1.1
Leptastrea bottae (Edwards & Haime)	111.....111...11111.1...
Leptastrea immersa Klunzinger	.........111...1....1...
Leptastrea inaequalis Klunzinger	..11111.................
Leptastrea solida Edwards & Haime	...............1........
Leptastrea pruinosa Crossland	1
Leptastrea purpurea (Dana)	1111111.1.11111111111..1
Leptastrea ehrenbergana Edwards & Haime	.........1........1.....
Leptastrea transversa Klunzinger	1111.11......1111111.111
Cyphastrea chalcidicum (Forskal)	1111....1111.1.11.1.1..1
Cyphastrea microphthalma (Lamarck)	111111..1.1.11.1111111.1
Cyphastrea serailia (Forskal)	111.111111..11.1.111...1
Cyphastrea suvadivae Gardiner	...............1........
Echinopora gemmacea (Lamarck)	1111.11.111111..1111....
Echinopora carduus Klunzinger	.........1..............
Echinopora hirsutisima Edwards & Haime	1.1.....1...1..11.......
Echinopora horrida Dana	1.1....................1
Echinopora lamellosa (Esper)	1111.1..111.11111.1.11.1
Echinopora concinna Vaughan	.........1..............
Echinopora mammiformis (Nemenzo)	1.1.....................
Echinopora spinulosa Brueggemann	...................1....
Trachyphyllia geoffroyi (Audouin)	11......1.1.1..1.....1.1
Galaxea cf. astreata (Lamarck)	1.1..1..........1......1
Galaxea clavus (Dana)	........1.1.11.1..1..11.
Galaxea lamarki Edwards & Haime	...............1........
Galaxea fasicularis (Linnaeus)	1111..1.1111.1111111.111
Galaxea hexagonalis (Edwards & Haime)	..............11..1.....
Parasimplastrea simplicitexta (Umbgrove)	.....11.................
Merulina ampliata (Ellis & Solander)	1111....111.11111....111
Merulina speciosa Verrill	1
Merulina scheeri Head	1.1.....................
Scapophyllia cylindrica Edwards & Haime	.....................1.1
Ctenella chagius Matthai	................1.......

Hydnophora exesa (Pallas)	1.111111111111.1111111.1
Hydnophora contignatio (Forskal)	.1.......1..............
Hydnophora grandis Gardiner	.............1.1........
Hydnophora tenella Quelch	...............1........
Hydnophora microconos (Lamarck)	1111.11.1111111111111111
Hydnophora rigida (Dana)	........1..............1
Merulina laxa Dana	.....................1..

Blastomussa loyae Head	111.............1.......
Blastomussa merletti (Wells)	1111111...11....1.......
Blastomussa wellsi Wijsman Best	11......................

Cynarina lachrymalis (Edwards & Haime)	11........1.11.1.......1

Scolymia vitiensis Bruegemann	..........1....1111.....

Acanthastrea angulosa=bowerbanki (E & H)	................11.1....
Acanthastrea echinata (Dana)	1111111.1111..111111...1
?Acanthastrea irregularis Quelch	.........1..............
Acanthastrea maxima Sheppard & Salm	.....11.................
?Acanthastrea hillae	.......1.1..............

Symphyllia agaricia Edwards & Haime	.............1.......111
Symphyllia erythraea (Head)	1.......................
Symphyllia radians Edwards & Haime	.....11......1111....111
Symphyllia recta (Dana)	1.11.....11..111.111.111
Symphyllia nobilis (Dana)	.......1...1...11.......
Symphyllia simplex Crossland	.........1..............
Symphyllia valenciennesii Edwards & Haime	1.1........1...1......1.
Symphyllia hassi Pillai & Scheer	...............1........

Lobophyllia corymbosa (Forskal)	1111.....11111111111.11.
Lobophyllia fistulosa (Edwards & Haime)	...............1........
Lobophyllia diminuta Veron	1
Lobophyllia hataii Yabe et al	1.1.....1..............1
Lobophyllia hemprichii (Ehreberg)	1111....11111..11111...1
Lobophyllia costata (Dana)	........111.1..11.1...1.
Lobophyllia pachysepta Chevalier	1.......................

Australomussa rowleyensis Veron	1

Echinophyllia aspera (Ellis & Solander)	1111111.11111..11111..11
Physophyllia ayleni? Wells	...............1........
Echinophyllia echinata (Saville-Kent)	1.11....................

Oxypora lacera (Verrill)	1111.1..111....11111...1

Mycedium elephantotus (Pallas)	1.11....1.1.1...1.1....1
Mycedium tenuicostatum Verrill	.........1.1......11....
Mycedium tubifex (Dana)	.1........11.1.1.....11.

Pectinia alcicornis (Saville-Kent)	...............1.......1
Pectinia lactuca (Pallas)	........1.11...1.1...111

Pectinia paeonia (Dana)	1
Pectinia teres Nemenzo	1
Euphyllia (F) ancora Veron & Pichon	................1......1
Euphyllia fimbriata (Spengler)	...............1......1.
Euphyllia (E) glabrescens (Cham. & Eys.)	11.1..1.....1111..1..111
Euphyllia turgida (Dana)	...............1........
Euphyllia (F) ?n. sp	................1.......
Plerogyra sinuosa (Dana)	1111....1.1....11.1..1.1
Physogyra lichtensteini (Edwards & Haime)	1.......1.111..11......1
Gyrosmilia interrupta Ehrenberg	1111....1.11.....11.....
Catalaphyllia jardinei (Saville Kent)	............1..1........
Catalaphyllia plicata (Edwards & Haime)	...............1........
Turbinaria crater (Pallas)	....1...1.1..1..1.1..11.
Turbinaria frondens (Dana)	1.1.....1....1.........1
Turbinaria magna Bernard	.........1..............
Turbinaria irregularis Bernard	.........1......1111....
Turbinaria marmorea Rehb.	...............1........
Turbinaria mesenterina (Lamarck)	11......111.11.11111...1
Turbinaria mollis Bernard	.....................1..
Turbinaria peltata (Esper)	....1111.11.11.1111..1.1
Turbinaria porcellana Bernard	................1..1....
Turbinaria reniformis Bernard	1.1.....................
Turbinaria veluta Bernard	.....................1..
Turbinaria stellulata (Lamarck)	1.1.............1......1
Turbinaria globularis Bernard	................1.......
Turbinaria stephensoni Crossland	..........1.............
Heteropsammia cochlea (Spengler)	....11......11.........1
Heteropsammia aphrodes Alcock	.........1..............
Heteropsammia geminata Verrill	.....................1..
Heteropsammia michelini (Ed. & Haime)	........1.1..1.1..1.....

ATOLL RESEARCH BULLETIN

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DISTRIBUTION OF THE MACRO- AND MEIOBENTHIC ASSEMBLAGES IN THE LITTORAL SOFT-BOTTOMS OF THE GULF OF AQABA (JORDAN)

BY

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P. VITIELLO AND A.H. ABU HILAL

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BY

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ABSTRACT

The spatial distribution of macro- and meiobenthic assemblages in organogeneous and terrigeneous sandy bottoms of the Jordanian coast of the Gulf of Aqaba was studied by SCUBA-diving. Transects were sampled along the shore in various types of bays and fringing coral reefs from beaches to the depth of 35 meters. Variations of densities as well as the main taxonomic groups are analysed according to sedimentary environments. In the embayed bottoms, macrobenthic densities show large fluctuations related to the types of biotopes (15,000-450 ind m^{-2}). They are homogeneous in sandy patches situated along the reef slopes. Polychaetes are largely predominant followed by sipunculids and bivalves. Meiobenthic densities vary between 0.3 to 5.4 $.10^{6}$ ind m^{-2} showing a decrease according to depth. Nematodes are dominant followed by copepods, nauplii, micropolychaetes, and other taxa like Kinorhynchs, Tardigrades, Gastrotrichs. Variations of macro/meiobenthos ratio are analysed according to ecological data. Comparisons with avaliable data in similar biotopes of the tropical indopacific area are developed.

INTRODUCTION

Soft-bottoms communities in the northern Gulf of Aqaba (Elat) were firstly described by Por and Lerner-Seggev (1966) and Fishelson (1971) following many papers dealing with taxonomic works (review in Fishelson 1971). Recent studies were devoted to : (1) the sandy beach assemblages (Hulings 1975a, b, Wahbeh 1976, D. Dexter 1979-survey, first data in Por 1983, Amoureux 1983) ; (2) the littoral communities of enclosed lagoons along the Sinaï peninsula (Jørgensen 1973, Kristensen 1973, Por & Tsurnamal 1973, Thane 1973a, b, Por 1974, Por & Dor 1975a, b, Por *et al.* 1977) ; (3) the shallow terrigeneous and coral bare sandy biota (Lawrence & Ferber 1971, Clarke 1972, Mergner & Schuhmacher 1974, Holthuis 1975, Ferber 1976, Mastaller 1979, Yaron 1979, Karplus *et al.* 1981, de Vaugelas & Saint-Laurent 1984 ; (4) the *Halophila* meadow epi- and endofauna (Hulings 1979b, Lipkin 1979, Zohary *et al.* 1980, Hulings & Kirkman 1982, Wahbeh 1982); (5) the deep slope infauna from Por's & Fishelson's dredgings (Bratcher & Burch 1967, Bonaduce *et al.* 1976, Schmalbach & Por 1977, Wägele 1981).

In same times, shallow and deep coral assemblages in the Gulf were finely described (Loya 1972, Mergner & Schuhmacher 1974, Fricke & Hottinger 1983, Fricke & Schuhmacher 1983).

In April-May 1981 a joint research survey (Univ. Nice and Univ. Jordan) was carried out upon infralittoral soft-bottom communities of the Aqaba Jordan coast within the framework of the large oceanographical and biological programme supported by the "Mission Océanographique française au Moyen-Orient". This survey included definition of meio- and macrobenthic assemblages according to environmental parameters (sediments, bacterial and diatom densities), as well as evaluation of bottom productivity (Bay 1982, Grelet *et al.* 1983, Grelet 1984, Falconetti & Thomassin to be published).

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ENVIRONMENTAL CONDITIONS

The Gulf of Aqaba represents one of the northern extensions of the Red Sea. It is a narrow and deep trench of the Syrian-African rift system (15-25 km width, depth down to 1,800 m) ; so, the infralittoral bottoms (down to about 100-110 m deep from Fricke & Schuhmacher 1983) are restricted to littoral narrow fringes just more extended in front of some wadi openings, mainly the northern Elat-Aqaba beach.

General climatic and hydrological conditions of the Gulf were reviewed by several authors (for recent paper, see Klinker *et al.* 1976, Paldor & Anati 1979). The main parameters influencing benthic fauna are the high salinity of water (about 41‰) and its high temperature (annual mean = 23°C). According to Mergner & Schuhmacher (1974) and Hulings (1979a), the surface water flows southward on both sides of the Gulf, while the deeper water flows northward along the east coast and southward along the west one. However, even a narrow tidal-range (0.4-0.7 m, max. 1.2 m in spring, Mergner & Mastaller 1980) is recorded, weak tidal currents were observed on reef flats and along the shallow outer reef slopes playing a role in food supplies of communities. In the narrow canyons and also in the bays, returned bottom currents probably occur as sediment distribution analyses point out.

Winds induce local swells but, in comparison with other oceanic environments, the northern Aqaba Gulf represents a weak-wave exposed littoral, more strengthened along beaches at the opened bays.

Nutritive richness of waters along the Jordan coast and the northern Aqaba beach is maybe increased by the possible occurrence of up-wellings, phenomena induced after strong wind periods (Anati 1974, Hulings 1979a). According to the arid climate of the region, the coastal waters do not receive silty terrigeneous inputs, therefore, they are very clear and are classified among the oceanic waters. Phytoplankton characteristics and nutrient levels are those of oligotrophic waters (Sournia 1977). However, as in all other tropical littoral environments, sediments harbour an high microphytobenthic productivity (Sournia 1977, Plante-Cuny 1978). From Pascal (1981), bacterial densities in the Jordan coastal waters vary between $1.11\text{-}2.20 .10^6$ in surface for non polluted areas and decrease in the Gulf midline. As recorded in the Pacific (Sorokin 1974), these values characterize coastal environments rather than oceanic environments.

The Jordanian coast is, as well as the Sinaï coast, characterized by a succession of bays (at the wadi openings) and of landheads upon which well developed fringing reefs take place (Friedman 1968, Gvirtzman & Buchbinder 1978, Guilcher 1979, Bouchon *et al.* 1982). Therefore, an alternate succession of terrigeneous and organogeneous (coral) sedimentary areas occur along the coasts (Erez & Gill 1977, Gabrié & Montaggioni 1982). As confirmed by our sedimentary data (Fig. 1 & 2, Table1) , the far end of the Gulf is occupied by the largest beach , at the wadi Arava opening. In some large bays, coral patches growth at intermediate depths (10-25 m); they might represent a first stage of the fringing reef building (Bouchon *et al.* 1982) or just to be in connection with local ridges encounter in front of the Pleistocene elevated reefs. The organic matter content of these sediments reach 0.07-0.26% for coral sands, 0.14-0.34% for seagrass sediments and 0.05-0.16% for terrigeneous bare sands (Wahbeh 1976, Hulings & Ismail 1978, de Vaugelas & Naïm 1982).

METHODS

Samples of macro- and meiofauna and sediments for grain-size and biochemical analyses were made in SCUBA-dives, along transects from beach to 35 meters (Fig. 1 & 2, Table 1).

Sediment analyses were done according to Weydert's 1976 methods; carbonate content was evaluated with Bernard's calcimeter. The method for determination of organic carbon content of sediments was that of Walkley & Black (1934) as described by Buchanan & Kain (1971).

Macrobenthos was sampled using an hydropneumatic sucker (Thomassin 1978a, Bussers *et al.* 1983) inside a frame (375 mm i.d.) until 40 cm maximum of depth with a 1.5 mm mesh sieve net. After preservetion in buffered formalin at 10%, macrofauna was sorted by CENTOB, Brest.

Meiobenthos was collected by coring sediment with transparent plexiglass tubes (36 mm i.d.) on the deepest thickness according to the nature of soft-bottoms; then conserved with buffered formalin at 4%. A Rose Bengal solution was used to facilitate sorting. The extraction of meiofauna was carried out by means of successive centrifugations and animals were collected on a 0.04 mm mesh-sieve.

RESULTS

Results obtained all along the Jordan coast of the Gulf of Aqaba concern, firstly the terrigeneous soft-bottoms in bays and canyon and, secondly the mixed and organogeneous sandy patches on coral fringing reefs (Table 2 & 3, Fig. 3, 4 & 5).

Terrigeneous Soft-bottoms in Bays and Canyon

Sedimentary bottoms in bays and canyon entrance result of the very occasional inputs of terrigeneous gravelly and sandy materials by littoral wadi; very fine sediment particles, transported by sand-winds, could be added in those sedimentary environments. So, the carbonate content in those bottoms is low, less than 10%. When the rate increases (in the deepest bottoms colonized by seagrass), it is connected with an input of the calcified epibiotic fauna living on the leafage (values vary between 10 to 18.5%).

The northern beach of the Aqaba Gulf (transect A). The far end of the Gulf of Aqaba is the largest beach of the littoral in front of the Arava wadi opening. This beach extends from Elat to Aqaba, a distance of almost 4 km. The infralittoral sampling stations, distributed from 1 to 25 m deep, were located in the upper levels in bare very fine sands and, down to 5 m deep, in a dense *Halophila stipulacea* meadow. Por & Lerner-Seggev (1966) described in these bottoms their "infralittoral *Lovenia elongata-Mactra olorina* community" (from low tide level to about 3-5 m deep) and the *Halophila* meadows. The first one corresponds to the deeper assemblage of the Fishelson's (1971) "*Hippa picta-Mactra olorina* community" whereas the second one is a part of his "*Halophila stipulacea-Asymetron (lucayanum ?)* community".
Macrofauna. Densities were high ; they varied between 1,500 individuals per square meter (ind m^{-2}) at 10 m deep to 1,100 ind m^{-2} at 25 m depth in the *Halophila* meadow. These densities, are related to a high dominance of polychaetes (54%) and sipunculids (16%) and represent the typical assemblage of this kind of seagrass bed.
Meiofauna. All samples gathered, this transect appeared the richest. A decrease of density was observed down to 5 m deep and the abundance was, at this depth, the highest recorded in this study (5,239 ind 10 cm^{-2}). Nematodes, copepods, nauplius larvae and micropolychaetes constituted the four main groups (dominance from 99 to 100%). Nematodes were the more numerous with a relative abundance varying between 68 to 91%, while micropolychaetes (0.70-3.50%) showed near homogeneous densities all along the transect.

The other embayed bottoms.
A) Transect E : This transect is an example of a typical bay transect ; it is located in the largest bay of the eastern coast of the Gulf ; it is flanked at its opening by two fringing reefs "kp 12" and "Cherif Nasser" and this bay has a well northern prevailing wind exposure.
Down to a gravelly beach (midlittoral zone), the shallowest bottoms (on the top of an upper embankment), consisted of fine to very fine sands colonized by belt-meadows of the seagrasses *Halodule uninervis* (0.5-1 m deep) then *Halophila ovalis* mixed with bare sand banks. Deeper, a dense *Halophila stipulacea* meadow occurs. Between 10 to 15 m deep, the first massive coral heads (*Porites*) occured at the foot of the sandy embankment while, deeper, spurs of coral growths were observed with their surrounding bare sandy bottoms and alternating *Halophila* meadows (with tumuli and funnels, down to 32 m deep). This is the typical physiography of the bottom before the drop-off occuring near 40 m deep.
Main faunistic assemblages in these infralittoral bottoms were those colonizing seagrass beds and their sand banks ("*Halophila* community", and those settling the bare coarse and medium coral sands "*Asymetron (lucayanum?)* community" Fishelson 1971).
Macrofauna. In the shallowest fine sands of the *H. uninervis + H. ovalis* belt meadows, large populations of polychaetes, actinians and sipunculids produced a density up to 15,000 ind m^{-2}, forming so a particular facies of the community. Deeper, in the *H. stipulacea* meadow, densities varied between 2,500 and 610 ind m^{-2} at 10 and 26 m depth respectively. Soft-bottoms assemblages along this transect were among the more diversificated. All the main zoological groups were well represented : polychaetes (33%), sipunculids (27%), crustaceans and actinians (15%), gastropods (3%), bivalves (2%) and they comprised 95% of the macrobenthos.

Meiofauna. Although this transect was less rich than the previous one, mean abundance of meiofauna was among the highest values recorded. As for macrofauna, the highest density was observed in the bare sand bank among the *H. uninervis* meadow, at 1 m deep. Down to a water depth of 16 m, densities decreased then, progressively, increased again down to 33 m deep. Copepods, nauplii larvae and, at a lesser degree, nematodes and polychaetes were responsible of this last increase. Nematodes were the dominant group (54-82% of total meiofauna) followed without a depth influence by copepods (10-36%), nauplii (2-9%) and polychaetes (1-8%).

B) Transect F. This southern bay is the most wave-exposed of the Jordan coast, and therefore exhibits a distinctive sedimentological patterns related to local topography. Below a gravelly midlittoral beach, a steep slope of coarse sediments extends down to 15 m deep, where it grades into a very fine sands colonized by a *H. stipulacea* meadows.

Macrofauna. In the gravelly midlittoral beach, density was high (1,720 ind m^{-2}) with a numerical explosion of polychaetes (*Polygordius ?*) (74%), of mole-crabs (*Hippa picta, H. celaeno*)(12%) and of the bivalve *Mesodesma glabratum* (8%). This was the typical assemblage of this upper level as described by Por & Lerner-Seggev (1966), Fishelson (1971) and Hulings (1975a). At a depth of 5 m, in coarse sands of the steep slope, density decreased down to 440 ind m^{-2}, while at its base, in a less mobile biotope the density increased again (1,250 ind m^{-2}). Deeper (25m), in the very fine sands of the *Halophila* meadow, this value was similar to the last one (1,270 ind m^{-2}).

Although polychaetes were predominant in these bottoms, a very low density of sipunculids (6%) appeared in the more stable sediments found at the deepest levels (from 15 m down to 25 m deep).

Meiofauna. Densities, as well as relative abundances of the main taxonomic groups, were reflected by the sedimentological characteristics of the bottoms of transect F, a transect that exibits the lowest densities in this study. Up to 15 m deep, coarse sands were unpropicious for a nematode settlement, particularly at a water depth of 5 meters where they just expressed 31% of total meiofauna; so, the main group consisted of nauplii (34.5%) and adult copepods were well represented with 29.7% of dominance. Deeper, sediments became finer with an increase of silts and allowed the settling of nematodes (74%). Despite this nematode increase, a decrease of meiobenthic densities was observed according to depth.

C) Transect B. This transect is located, in front of the Marine Science Station, at the top of a strait and deep canyon flanked by fringing coral reefs. Samples were taken, firstly in an hydraulic fine sand bank (3 m deep) at the entrance of the Marine Station harbour, secondly in the canyon axis in very fine sands fixed by dense *H. stipulacea* meadow (10-15 m deep), and finally in medium sands colonized by scarce seagrasses (25 m deep).

Macrofauna. Density increased between 3 and 15 m deep from 840 to 2,160 ind m^{-2} then decreased, deeper, down to 600 ind m^{-2} . Community was largely dominated by polychaetes, particularly at a water depth of 15 m in the dense meadow where they reached 61%. Principal zoological groups were well represented (polychaetes : 61% ; sipunculids : 10% ; bivalves and gastropods : 7 and 3% ; actinians : 6%). Sipunculid dominance increased between 10-15 m deep in the seagrass meadow which correlated to a higher silt ratio and, probably, to an increase of the organic matter content.

Meiofauna. The highest density (3,246 to 677 ind 10 cm -2) was observed in shallower *Halophila* meadow while a decrease of total number of meiobenthos was recorded according to depth. Adult copepods and nauplii densities increased in the washed, cleaner sands of the upper levels (3 m deep) as well deeper (25 m deep), because of better oxygenation of sediments

Mixed and Organogeneous Sandy Patches on Coral Fringing Reefs

Two transects were studied on flats and outer slopes of the coral fringing reefs of kp. 8 and kp. 12 (transects C and D). In residual pools of the narrow inner reef flat (named as "reef lagoon" by Mergner & Schuhmacher 1974, "boat channel" by Bouchon 1980, "backreef channel" by Bouchon *et al.* 1982), between 1-2 m deep, the thin sedimentary layer (a thickness of 15-20 cm) is colonized along the littoral by patches of seagrasses (*Halodule uninervis* and *Halophila stipulacea*). These sediments were fine to very fine sands, sometimes little clogged by silts and, according to their low carbonate content (41-67%), they belonged to the "impure carbonate facies". In front of reef flats, from the small cliff base (5 m deep) down to 25 m on the outer reef slopes, medium coral sands have cumulated in pockets between coral growths or patches. Down to a water depth of 25 meters, the topography of the slope changes : large basins filled with fine

coral sands (30-35 m long and 3-5 m wide) cut across the coral-covered fore-reef slope.

Two types of faunistic assemblages could be recognized along these two transects : (1) the sparse seagrass meadows (narrow *Halodule* belt and *Halophila* meadows)(Por & Lerner-Seggev 1966, Fishelson 1971, Wahbeh 1982); (2) the clean medium-size coral sands colonized by the "*Asymetron (lucayanum ?)* community" of Fishelson (1971).

Macrofauna. Accepting that reef flat samples were not taken in account, highest densities were recorded at the foot of the reef flat cliff (at 5 m deep) in fine sands (1,200 and 950 ind m^{-2}) while a population decrease was observed in sandy pockets of the outer slope (810 and 560 ind m^{-2}).

Deeper, in sandy depressions, densities seemed to increase in relation to larger surfaces of sediment and its stability (940-770 ind m^{-2}) while they decreased near 35 m deep in finer sands (730 ind m^{-2}).

The macrobenthos here was also mostly composed of polychaetes (64%). Sipunculids were sparce in clean and well oxidized sands while an increase of bivalves (8%) was recorded with an increase of depth down to 25 m deep.

Meiofauna. Densities varied in relation with depth as well as with sediment parameters. The abundance along transect C were lower than those recorded along transect D. For the two transects, densities of total meiofauna decreased from upper levels to mid-outer reef slope (23-25 m deep), but the density somethimes did increase again in the deepest sandy patches (as at 35 m deep, transect D). Nematodes, copepod adults and nauplii larvae were always the main taxonomic components of meiobenthos (91-99%). Kinorhynchs were present only in orgageneous sediments, but lacking silt were never abundant (O.O5-1.9%).

DISCUSSION

General Features of Macrobenthic Densities

Variations according to sedimentary environments. From the sediment analysis, it was pointed out two environmental types of soft-bottoms (compactness and thixotropy of sediments being correlated with their carbonate content: organogeneous and terrigeneous sands, our data corroborating those obtained by Gabrié & Montaggioni (1982) and de Vaugelas & Naïm (1982). To understand the variation of macrobenthic densities according to these both environments, transects were classified following mean-density values (Table 4).

From Table 4, the terrigeneous quartzitic sands, in front of wadi openings, appeared to be colonized by a richer macrobenthos (1,400 $< \partial <$ 1,200 ind m^{-2}) than the coral sands of outer fringing reef slopes (950 $< \partial <$ 800 ind m^{-2}). Transect B, in terrigeneous sandy bottoms of a narrow canyon flanked by fringing reefs, seems to correspond to a peculiar zone between these two sedimentary environments: a narrower bottom surface, linked with sediment gravity currents, could induced here a macrofaunal decrease .

Variations according to depth. Analyses of macrobenthic densities variation according to depth (Table 2) revelated three features : (1) in bays, where nature of bottoms was more heterogeneous, differences among sampled densities were more pronounced (2,520 down to 190 ind m^{-2}) than in organogeneous sands of outer fringing reef slopes (959-550 ind m^{-2}); (2) density fluctuations were narrowest below a water depth of 15 m. They appear to be independent of sedimentary environment, and related to more stable conditions than those found in shallower wathers; (3) highest densities were recorded at about 15 m deep , mainly in terrigeneous very fine sands colonized by *H. stipulacea* meadows, or in their vicinity.

Variations of faunistical composition. Principal taxonomic groups of macrobenthos were polychaetes (82-37% of dominance), sipunculids (34-2%) and bivalves (11%). However, some remarks concerning other groups could be noted : (1) abundance of burrowing actinians in shallow bare sand banks, covering by *Halodule/Halophila* beds, could represent a facies of the faunistic assemblage ; (2) abundance of the lancelets *Asymetron lucayanum* in some medium sands could characterize some aspect of the assemblage (23-27%, as in transect C at 15 m deep and transect B at 25 m) ; (3) presence of juveniles of a burrower brachyopod, *Lingula sp*., recorded in terrigeneous sands (transect E, 26 and 33 m deep) and in coral sands at the upper reef outer slope (transect C, 5 m deep).

General Features of Meiobenthic Densities

Variations according to sedimentary environments. At the opposite of the macrobenthos distribution, densities of total meiobenthos, nematodes and copepods did not show significant variations according to (biogeneous or terrigeneous) nature of sediments (non-parametric statistical Man-Whitney U test used). The only differences noticed concerned : (1) the exclusive presence of kinorhynchs living in carbonate sands and (2) the high relative abundance of nematodes in very fine sediments, more often terrigeneous. In contrast with terrigeneous sands, a highly significant linear correlation (**r** = -0.88 ; n = 9) could be demonstrated in the organogeneous ones between meiofaunal densities and sediment mean-size, meiofauna increasing in finer sands (see below, relation with depth).

Variations according to depth (Fig. 4). In soft-bottoms of the Jordan coast, meiobenthic densities varied from 263 to 5,329 individuals per 10 cm^{-2}. All along transects, a decrease of density was observed from beaches to a water depth of 25 m. At this depth, density values became more homogeneous reaching near 1,000 ind 10 cm^{-2}.

In the mid-northern part of the Jordan littoral (transects A, B, C), an optimum density was recorded near 5-10 m deep, whereas in the southern part (transects D, E, F) an enrichment occured down to 25 m deep. Schmalbach & Por (1977) in their dredgings along the Gulf midline recorded highest density in shallow (1-5 m) and deep (50-250 m) water and lowest in mid-depths (10-50 m).

To explain this fact, several considerations can be given. The low density values observed between 1-5 m deep in the northern littoral, as also the enrichment recorded in the southern area down to 25 m deep, seem to be induced by particular hydrodynamic conditions in relation to bottom topography. Firstly, the wave action in the upper levels of soft-bottoms (between 0-2 m deep) is more pronounced in the northern littoral (inner area of the Gulf) and could limit the meiofaunal settling. It is promoted deeper (down to 3 m deep) by lower water agitation allowing deposition of finer sediments, and by bottom stabilization induced by the seagrass meadow growth. Secondly, a break in slope, parallel to the Jordan coast, occurs around 20-25 m on the outer reef slopes, and near 40 m deep all along the littoral (Bouchon *et al.* 1982), and corresponds to submerged Pleistocene terraces (Gvirtzman & Buchbinder 1978, Fricke & Schuhmacher 1983). The upper slope break could locally strengthen deep water currents, inducing an increase of the sand mean-size as well as a better oxygenation of sediments which are enriched in organic matter derived from nearby *Halophila* meadows. All these environmental conditions are propitious to the meiofaunal settling, characterized by a development of copepods and nauplius larvae.

The highest densities were recorded at shallow depths (from 1 to 10 m deep) in the vicinity of *H. stipulacea* meadows and in very fine sands, more often terrigeneous, and generally less sorted and less graded. These seagrass beds stabilize the sediments as well as they enrich them in organic matter, directly or indirectly, by trapping particles. This leads to analyse the role of the organic matter content on meiofauna distribution.

Variations according to organic matter content of sediments. Organic matter content of the Jordan littoral sediments was analysed by Wahbeh (1976), Hulings & Ismail (1978), de Vaugelas & Naïm (1982). In our study, we recorded the following values of organic carbon (% of dry weight) : 0.17-0.53 in coral sands, 0.09 in bare terrigeneous sands, and 0.06-0.53 in *H. stipulacea* meadows. These data are in accordance with those of the authors cited above. But, they demonstrated that the total organic matter content shows good correlation (1) with carbonate content : terrigeneous sands showing the lowest values whereas organogeneous ones have the highest, (2) with sediment grain-size: the finest sands show the highest values. These last results do not agree with ours because we could not shown relations between organic matter content and (1) carbonate content and (2) sediment grain-size.

As well as in terrigeneous or in organogeneous soft-bottoms, densities of meiofauna were relatively well fitted to fluctuations of the organic carbon content.

Nevertheless, an enrichment of organic matter from seagrass meadows in well oxygenated sediments seems to be a factor favoring the meiobenthic settling; particularly in shallow depths where the availability of a high energy for primary producers induces a higher production of organic matter, secondly recycled by bacterial processes; food sources are well diversified for the meiobenthos. This could explain the highest densities (more than 2,000 ind 10 cm^{-2}) recorded in the shallowest bottoms (up to 10 m deep).

Variations of faunistical composition (Table 3, Fig. 5). In all samples, nematodes were largely dominant in the meiobenthic assemblages (32-91%). Examination of all transects (transect F being excluded according to its singularity) showed highest proportion of nematodes at intermediate depths (5-15 m deep) in terrigeneous bottoms of bays whereas, in reefal organogeneous sands, the phenomenon was inverted. The wave action (between 0 to 2 m deep) and the deep currents (near 20-25 m deep) creating a bottom instability could induce a decrease of the relative abundance of nematodes at these depths (Fig. 5). Copepods represented the second group (5-36%) and nauplii the third (2-35%). Most of the copepods were Harpacticoids (excepted some epibenthic species) and probably most of the nauplius larvae belong to them. Micropolychaetes were the last group recorded in all samples. Their study lacks in precision so, it is difficult to know the proportion of worms belonging to the true meiofauna or to the temporary meiobenthos (juveniles of macrobenthic species). Other groups, as gastrotriches, kinorhynchs, oligochaetes, tardigrades, acarians, ostracods, tanaids and isopods, were poorly represented. Kinorhynchs were only sampled in organogeneous sands while tardigrades showed a larger sedimentological distribution.

Analysis of Macro-Meiobenthic Relationships

The difference in the soft-bottom infauna of the two sedimentary environments (terrigeneous and organogeneous) appeared mainly in density fluctuations of macrobenthic assemblages, as demonstrated above. However, when density variations of macrofauna and meiofauna were analysed (Fig. 6), it was pointed out : (1) inverse fluctuations in terrigeneous bottoms (particularly clear along transect B, in the Marine Station canyon at kp. 8, and between 5-15 m deep along transect F) ;(2) similar profiles in biogenic bottoms, between 15-23 m deep on outer reef slopes (transects C, D).

Variations of macro/meiobenthic ratio (Table 5, Fig. 6) showed a large range; with values of 1/271 (transect C, 25 m deep) and 1/17,100 (transect B, 10 m deep). This ratio generally increased at the vicinity or in the *H. stipulacea* meadows (mean : 1/1,237) where high densities were recorded for the both great benthic groups, but mainly for macrobenthos. In bare sandy bottoms, terrigeneous and organogeneous environments could be distinguished. In the first one, the mean value of the ratio was low (1/5,437) mainly because of low abundance of macrofauna and high density of meiobenthos (at 10 m deep, transect B, density of macrofauna was exceptionally low and the one of meiofauna high, so the ratio was equal to 1/17,000 ; if this station was excluded, mean ratio was 1/2,521). In the second one, the mean value of the ratio is higher (1/1,889) with a lower variability: 18% whereas in terrigeneous samples it was 54% (variability = ratio between standard-deviation and mean value of the macro/meibenthos ratio, expressed in %).

For a general point of view, gathering all the stations, the both sedimentological environments could be recognized. In terrigeneous sediments, values of the macro/meiofauna ratio were lower (mean value = 1/2,668) and less homogeneous (variability = 43%) than in biodetrital ones (mean = 1/1,889 ; variability = 18%). The relative homogeneity of this ratio in organogeneous biota seems to be connected with macrofauna density.

If macrobenthos/meiobenthos density ratio is usually used (McIntyre 1969, Thomassin *et al.* 1976, 1982, for example), its analysis is critical. So, another method was attempted. For each sediment grain-size classe, the wrapping surface of stations was drawned according to densities and depth (Fig. 7). From this graph it appeared that (1) the very fine sand assemblages showed large range of densities according to depth but more important for meiofauna, abundances of which decreasing to 24 m deep whereas this fact was less accurate for macrofauna that had a wider wrapping surface; (2) in fine sands, population fluctuations were particularly narrow, near closed in the shallow bottoms (0-5 m deep) then densities increased for both great benthic groups and, near 33-35 m deep, the variations were rather inverse; (3) in medium sands, mainly biogeneous, density variations were also low, but with some opposition between macro- and meiobenthos: macrofauna reached 550-950 ind m^{-2} at all depths whereas meiofauna decreased from 5 to 25 m deep, reaching its lowest densities.

Comparisons with other Tropical Indopacific Littoral Communities

The benthic communities colonizing the infralittoral shallow soft-bottoms of the Gulf of Aqaba belong

to four biocenosis, as defined (Thomassin 1978b, 1983) for the indopacific littoral assemblages, as follows: (1) the "Biocenosis of the well sorted fine sands" colonizes the shallow bare sandy bottoms of the wave-exposed beaches. It corresponds to the true "*Lovenia elongata-olorina* c ommunity" defined by Por & Lerner-Seggev (1966). The *Hippa picta-Mactra olorina* community" (Fishelson 1971) gathers two assemblages : the former biocenosis and the intertidal midlittoral sand assemblage ; the last one is not a biocenosis but a permanent group (Bigot & Picard 1984) and it is equivalent to the " *Hippa* community" (Por & Lerner-Seggev 1966) or the " *Hippa - Mesodesma* community" (Hulings 1975a); (2) the "Biocenosis of the sheltered muddy sediments", in its less sediment clogging aspects with the epifloral facies (seagrass beds), is represented in the Gulf of Aqaba by the *Halophila stipulacea* and *Halodule uninervis* meadows (the scarce *Halophila ovalis* beds are associated with the more clogged medium clean sands colonized by the third biocenosis, see below; the *Thalassodendron ciliatum* and *Syringodium isoetifolium* beds are more developed along the southern coast of Sinaï and in the Red Sea, see (Crossland 1938, Fishelson 1971, Lipkin 1975, 1977). The *H. uninervis* meadows are not well developed all along the Jordan coast and they are located in bays or fringing reef residual pools as very shallow belts. At the opposite, the *H. stipulacea* meadows colonize most of the bottoms in bays (down to 50-60 m deep) with a high productivity (Hulings 1979b, Lipkin 1979). General macrofauna of these beds is described *pro parte* by Fishelson (1971) in his *Halophila stipulacea - Asymetron (lucayanum ?)* community ". However, a large part of fauna of his "*Ptychodera flava - Radianthus koseirensis* community" belongs to this biocenosis; (3) the "Biocenosis of the coarse and medium sands under bottom stream effects" colonizes the clean organogeneous sediments mainly on fringing reefs (outer flats and outer slopes) and also the sandy patches around coral heads growing in the middle of some bays. This last biocenosis overlaps the " *Asymetron (lucayanum ?)* community " (Fishelson 1971). It is well distributed in coastal environments at the vicinity of coral reefs so, in the "coralline algal shelly strait bottoms" (for recent Red Sea data, see Mastaller 1979, Bertz & Otte 1980).

But, to be unbiased, comparisons of benthic populations densities must utilize data coming from samples taken using similar methods (sampling, sorting and counting, evaluation of environmental parameters, see Methods). Therefore, for a quantitative point of view, available data for tropical indopacific littoral communities are few in the literature.

Macrofauna. According to above, only the following works can be used for quantitative comparisons : from Tulear, Madagascar (Pichon-Mireille 1965, Reys & Reys 1966, Le Fur 1972 re-analysed in Thomassin 1978b); from Soudan, Shab Baraja reef (Betz & Otte 1980); from Australia Great Barrier Reef, Lizard I. (Jones 1984); from French Polynesia (Thomassin *et al.* 1982). In coral sands colonized by the " *Asymetron lucayanum* community ", macrobenthic densities recorded at Aqaba on outer reef slopes (560-1,200 ind m^{-2}) were similar to those of equivalent sedimentary biota in another areas (Table 6). Richest populations were always observed in bottoms submitted to currents carrying detrital organic matter from seaward biotopes increasing the suspensivorous and filter feeders. High densities recorded in Shab Baraja coral reef sediments could be explain by the 0.5 mm sieve-mesh size used (42,480-30,599 ind m^{-2} in enclosed lagoon ; 12,125-5,981ind m^{-2} in outer reef slope).

In dense *Halophila stipulacea* meadows, densities varied more at Aqaba (1,130-2,520 ind m^{-2})than in the Tulear barrier reef complex (1,127-1,733 ind m^{-2}). The highest density was observed in the shallowest *Halodule* belts of Aqaba and, at Nosyve I. (Tulear region), in a near closed environment, it was also recorded a macrofauna increase(4,547 ind m^{-2}).

Meiofauna. Quantitatively, only the de Vaugelas's study (French Polynesia, 1980) can be well utilized (same methods used) for comparisons of infralittoral data in the indopacific area.

In shallower bottoms, meiobenthic densities recorded at Moorea I. and at Aqaba were similar (1,000 to 5,830 ind 10 cm^{-2} at 0.3 m deep in a lagoon of the Tiahura reef complex into the 0-2 cm surface layer against 1,972 to 3,265 ind 10 cm^{-2} at 1-5 m deep in the Aqaba reefs into the 0-5 cm surface layer). In deeper bottoms, at 25-35 m deep, meiofauna of the Gulf of Aqaba was poorer than in lagoonal bottoms of Vairao reef complex, Tahiti I. (at Aqaba, densities varied between 1,555 and 1,936 ind 10 cm^{-2} in embayed bottoms against 5,498 ind 10 cm^{-2} in muddy fine sands under more terrigeneous clay inputs at Tahiti). In Polynesia, meiobenthic densities decreased from coarse to fine sediments and the opposite occured at Aqaba, these facts being correlated with different physiographical environmental conditions.

Available data of meiobenthic densities from tropical Indopacific seagrass beds (belonging as epifloral facies of the "Biocenosis of sheltered muddy sediments" as defined by Thomassin in 1978b and Vasquez-Montoya 1979) refered to reef flat seagrass beds (*Cymodocea-Halodule*) in SW New Caledonia (Thomassin pers. comm.) where densities seemed to be of the same order of magnitude than those recorded at Aqaba (3,703 ind 10 cm^{-2} and 2,147 ind 10 cm^{-2} in New Caledonia against 677-3,732 ind 10 cm^{-2} and 571-2,831 ind 10 cm^{-2} at Aqaba for total meiofauna and nematodes, respectively). Other densities, recorded in muddy bottoms (near mangrove belt) of the Sinaï coast, fluctuated between 130-249 ind 10 cm^{-2} and 138-822 ind 10 cm^{-2} (Thane 1973a, b) showing that these peculiar biotopes were less rich than the *Halophila* meadows. Though thier study of the Florida Keys sediments, Decho *et al.* (1985) showed a significantly lower total meiofauna density in seagrass area than in adjacent barren sand area as at Aqaba; according to Evans (1983) and Hooks *et al.* (1976), these authors suggest that for macrofauna abundances of smaller predators are controlled by larger predators in open areas and, therefore, the seagrass bed serves as a refuge from predation for macrofauna. Consenquently, by a presence of a greater number of potential predators of meiofauna, predation pressures on meiobenthos could be higher in seagrass sediments than in adjacent bare sands. However, the vicinity of seagrass beds would represent a potential source of organic carbon which could be utilized, directly or not (bacterial processes, diversification of food sources), by the meiofauna, so in these biotopes densities are high.

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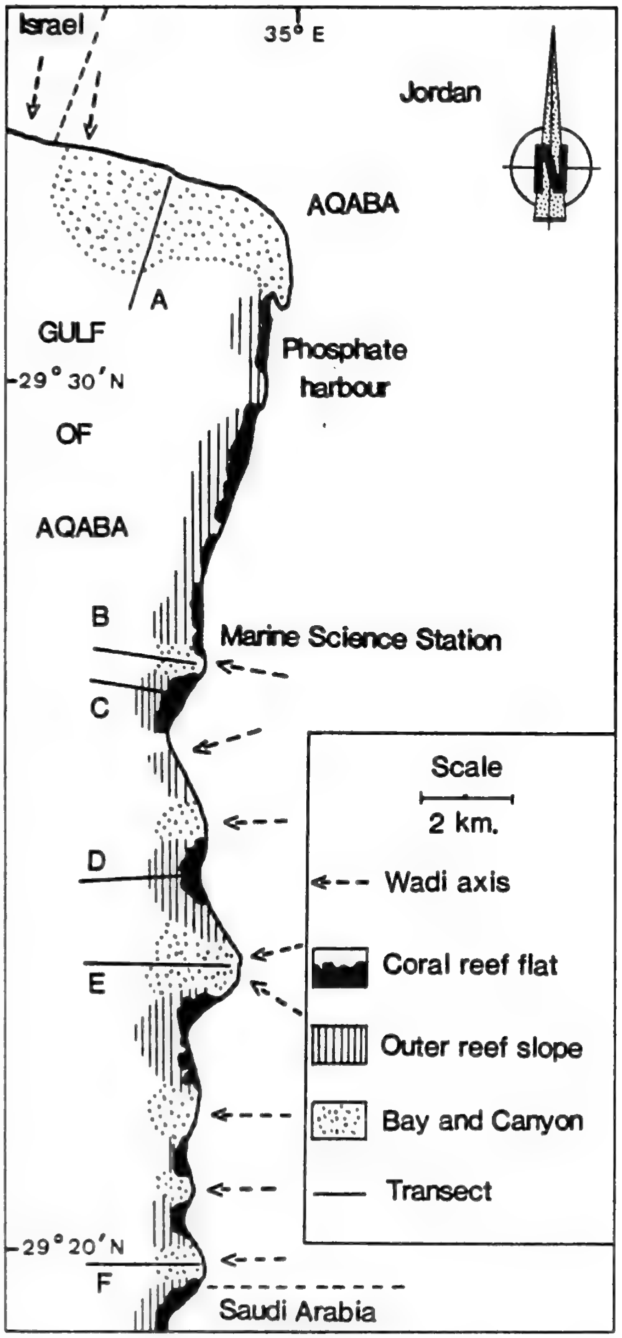

Fig. 1. North-eastern coast of the Gulf of Aqaba with location of the sampling transects (map from Gabrié & Montaggioni, 1982).

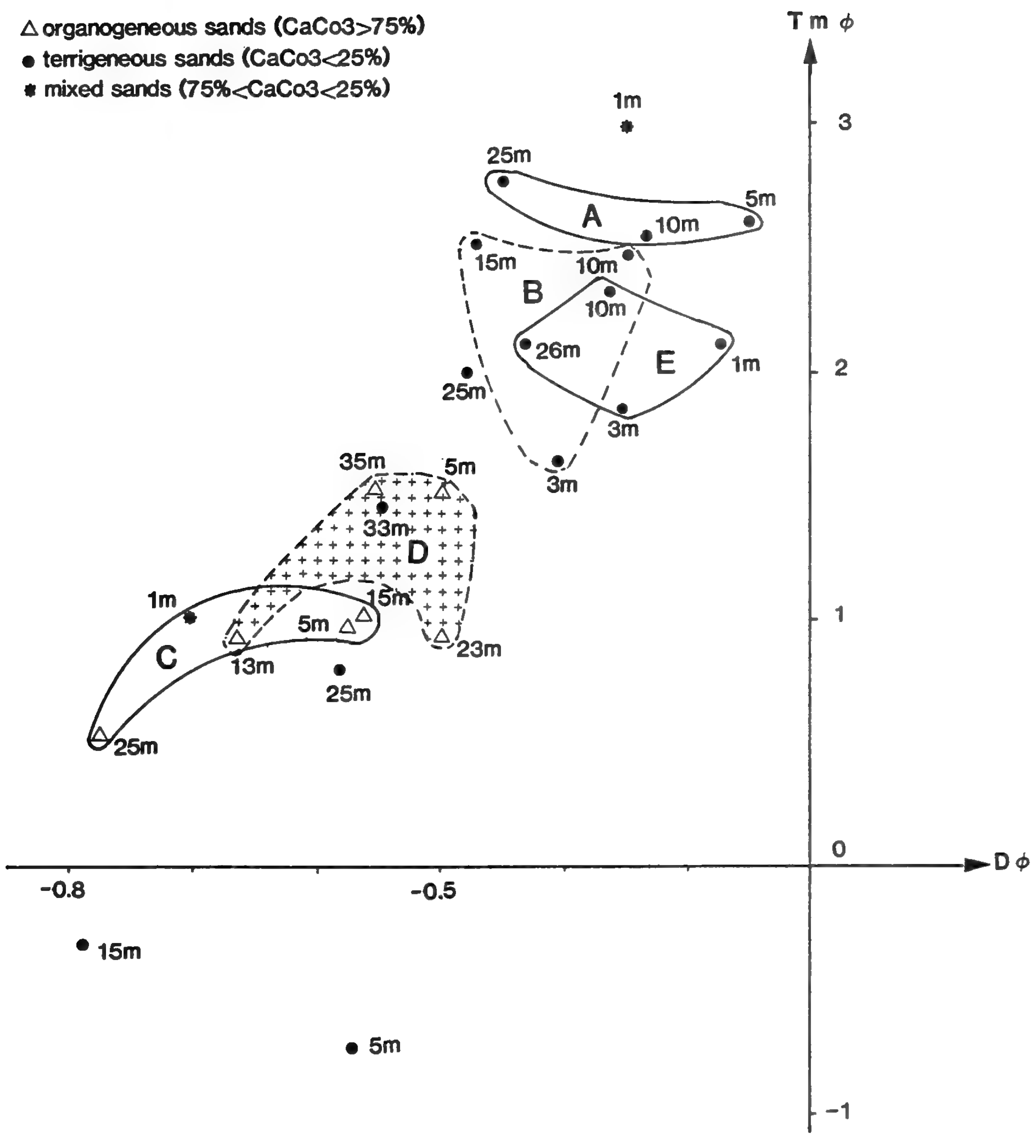

Fig. 2. Sedimentary stocks according to mean-size (Tmø) and sorting index (Dø) (phi scale).

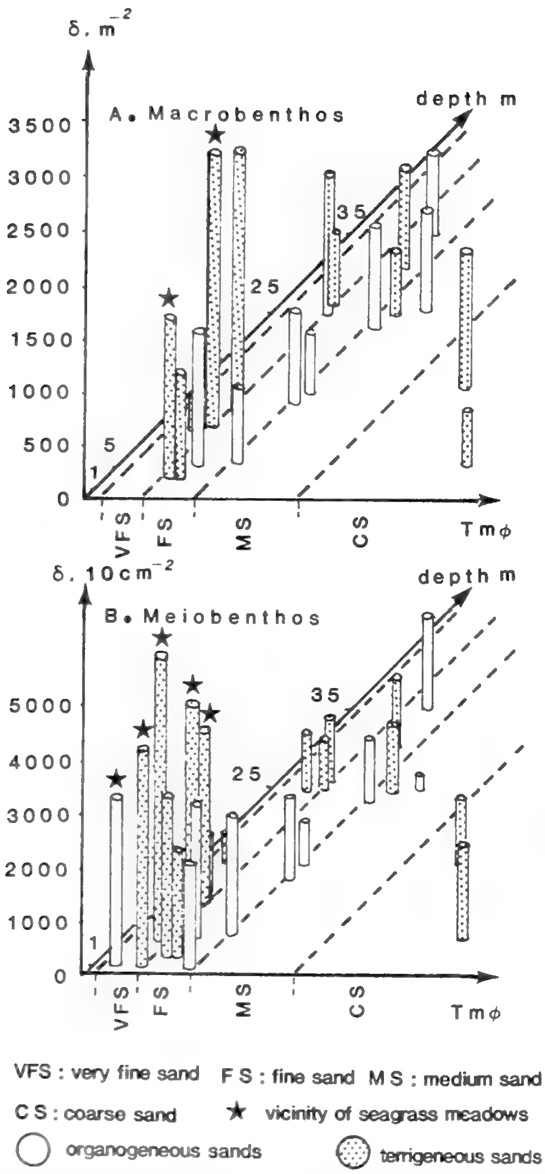

Fig. 3. Variations of macrobenthic (A) and miobenthic (B) densities according to depth and sediment mean-size (Tmø).

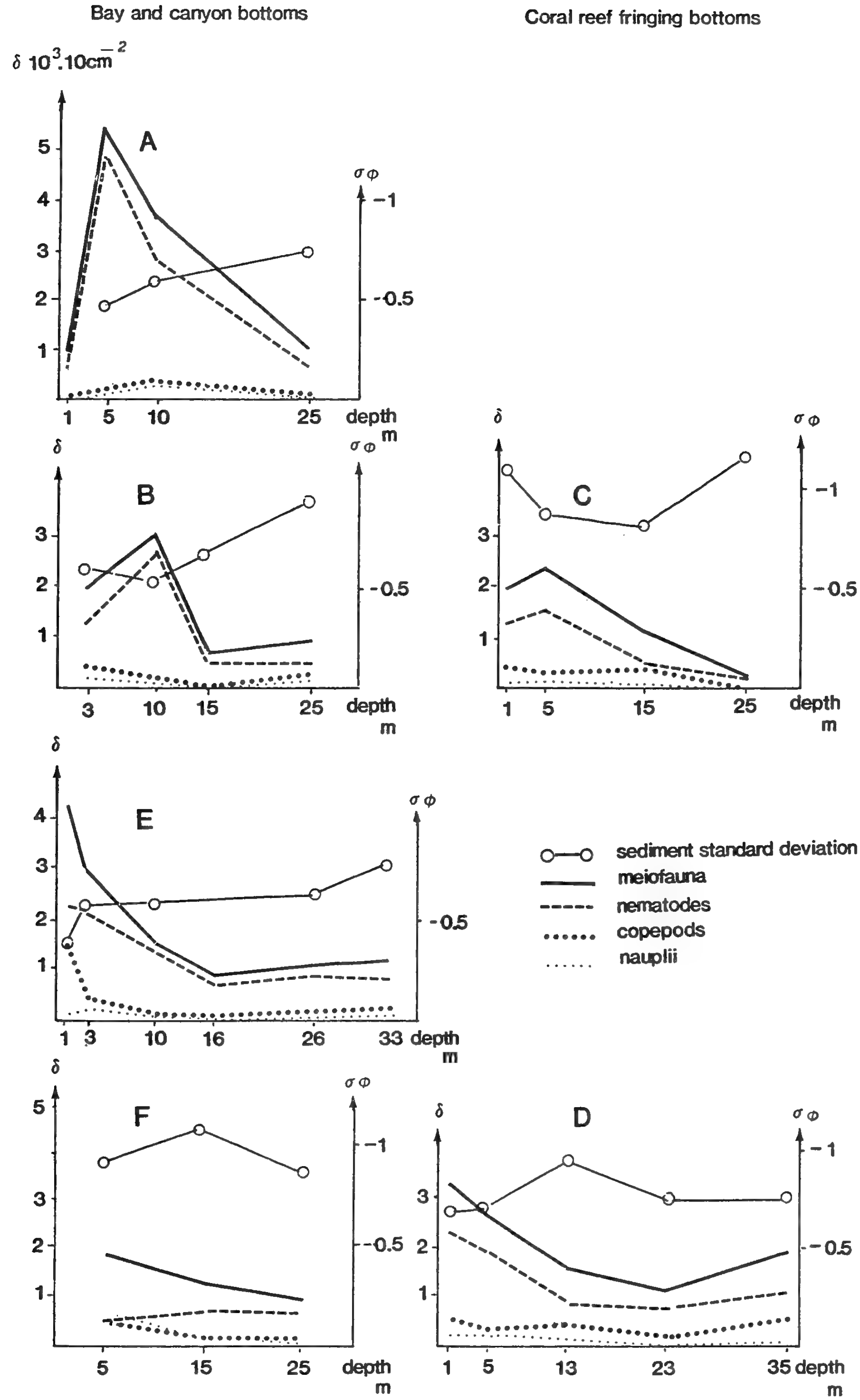

Fig. 4. Variations of meiobenthic densities according to depth and sediment standard deviation (ø).

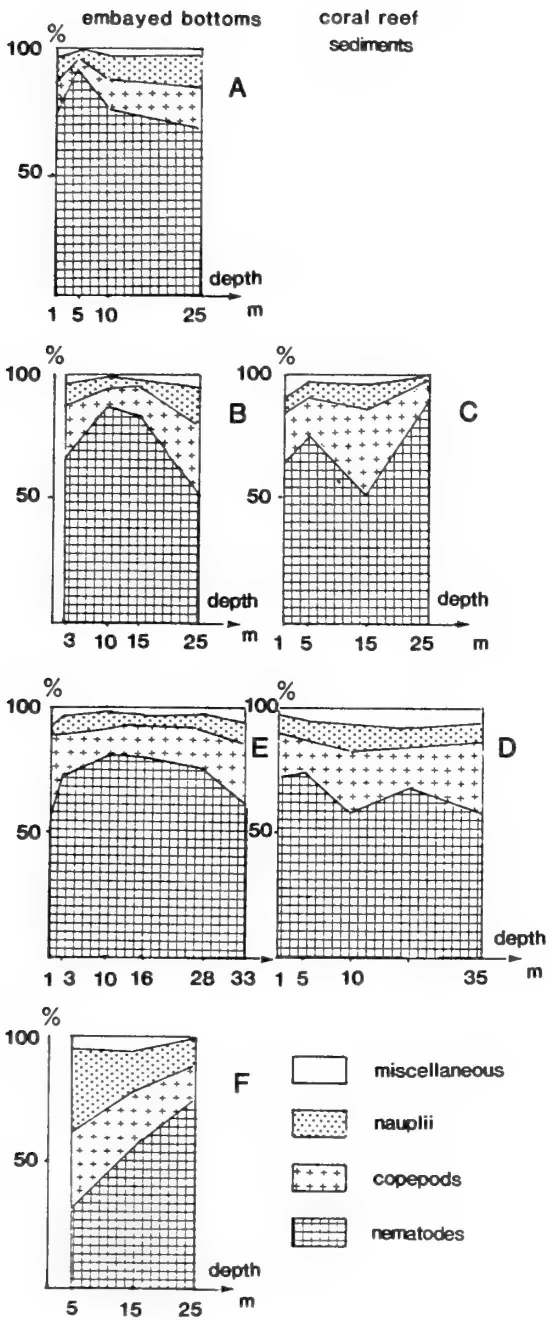

Fig. 5. Fluctuations of major meiobenthic groups along the various transects according to depth.

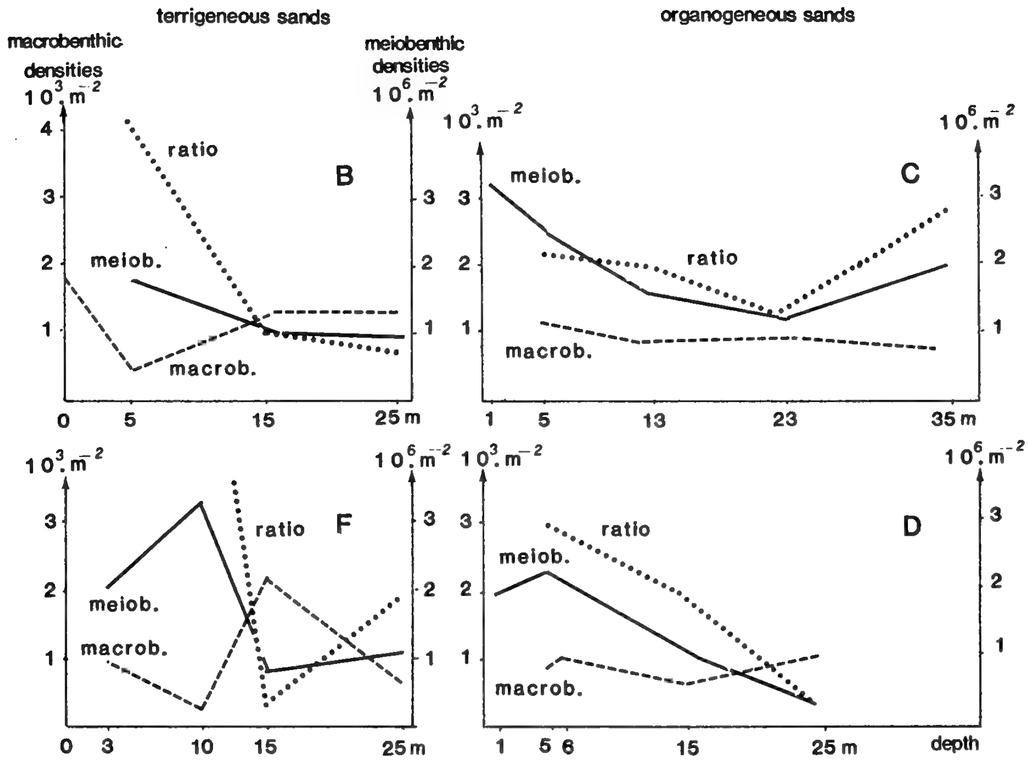

Fig. 6. Macro- and meiobenthic relations along selected transects, according to depth in terrigeneous and organogeneous sands .

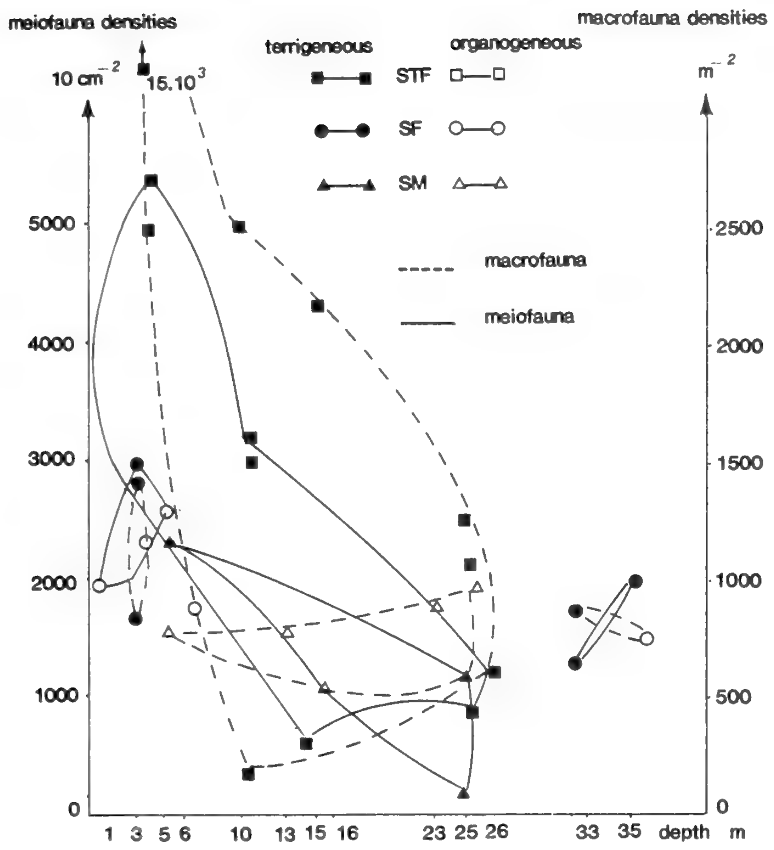

Fig. 7. Density fluctuations of macro- and meiobenthos according to sedimentary stocks. (STF = very fine sands; SF = fine sands; SM = medium sands).

Table 1. Sediment data along sampling transects, Aqaba Jordan coast, April-May 1981. (CS = coarse sands;
MS = Medium sands; FS = fine sands; VFS = very fine sands; organic carbon content in % of dry weight).

SAMPLING TRANSECT	DEPTH (m)	MEAN SIZE Tmø		KRUMBEIN sorting Dø	FALK & WARD standard deviation σø	SILT and CLAY (%)	$CaCO_3$ (%)	ORGANIC CARBON (%)
A	5	VFS	2.60	-0.24	-0.47	2	7.2	0.28
	10	VFS	2.55	-0.36	-0.59	5	11.3	0.13
	25	VFS	2.76	-0.46	-0.74	16	18.5	0.27
B	3	FS	1.62	-0.41	-0.59	0	5.9	-
	10	VFS	2.40	-0.35	-0.54	1	9.0	-
	15	VFS	2.51	-0.47	-0.68	8	10.5	0.09
	25	MS	0.80	-0.58	-0.94	0	6.6	0.21
C	1	FS	1.07	-0.71	-0.08	3	66.8	0.48
	5	MS	0.94	-0.57	-0.87	1	85.6	0.26
	15	MS	0.97	-0.56	-0.82	0	73.8	0.17
	25	MS	0.53	-0.76	-1.16	3	80.2	0.18
D	1	VFS	2.98	-0.35	-0.68	9	41.0	0.53
	5	FS	1.51	-0.50	-0.70	1	75.4	0.38
	13	MS	0.94	-0.66	-0.95	3	82.8	0.21
	23	MS	0.91	-0.49	-0.76	0	83.1	0.26
	35	FS	1.47	-0.55	-0.77	1	84.4	0.39
E	1	VFS	2.14	-0.27	-0.38	0	8.4	0.31
	3	FS	1.82	-0.36	-0.57	2	8.1	0.19
	10	VFS	2.36	-0.37	-0.57	2	9.2	0.06
	26	VFS	2.15	-0.43	-0.62	1	13.3	0.09
	33	FS	1.40	-0.54	-0.78	1	11.2	-
F	5	CS	-0.70	-0.57	-0.91	0	-	-
	15	CS	-0.34	-0.77	-1.09	11	6.3	0.48
	25	VFS	2.06	-0.48	-0.87	16	12.3	0.31

Table 2. Densities of macrofauna (ind m^{-2}) along the sampling transects, Aqaba Jordan coast.

	EMBAYED AND CANYON BOTTOMS		FRINGING REEF	CORAL BOTTOMS	EMBAYED BOTTOMS	
Depth (m)	Transect A	Transect B	Transect C	Transect D	Transect E	Transect F
0						1,720
1					15,060	
3		840			1,490	
5			780	1,200		400
6			950			
10	1,510	190			2,520	
13				810		
15		2,160	560			1,250
23				940		
25	1,130	600	970			1,270
26					610	
33					850	
35				730		
means	1,320	948	815	920	4,106	1,170

Table 3. Density (ind 10 cm^{-2}) and percentage of meiobenthic groups along the sampling transects.

SAMPLING TRANSECT	DEPTH (m)	NEMATODES	COPEPODS	NAUPLII	MICRO-POLYCHAETES	KINORYNCHS	TARDIGRADS	MISCELLANEOUS (GASTROSTRICHS OLIGOCHAETES ACARIANS OSTRACODS TANAIDS)	TOTAL MEIOFAUNA
A	1	677 73.43	111 12.04	100 10.85	32 3.47		1 0.11	1 0.11	922 100%
	5	4,837 90.80	259 4.90	187 3.50	35 0.70		4 0.07	7 0.13	5,329 100%
	10	2,839 76.10	414 11.40	363 9.70	51 1.40		9 0.24	58 1.55	3,734 100%
	25	724 68.20	172 16.20	138 13	22 2.10		2 0.18	5 0.47	1,063 100%
B	3	1,340 66.40	426 21.20	181 9.00	61 3.00		1 0.04	4 0.19	2,013 100%
	10	2,840 87.49	215 6.60	171 5.30	18 0.60		2 0.06		3,246 100%
	15	571 84.34	76 11.23	13 1.92	12 1.77		4 0.59	1 0.15	677 100%
	25	586 53.10	291 26.40	163 14.80	53 4.80		4 0.36	8 0.72	1,105 100%
C	1	1,275 64.70	394 20.00	124 6.30	136 6.90	1 0.05	36 1.82	5 0.25	1,971 100%
	5	1,742 75.80	384 15.10	152 6.60	41 1.80	1 0.04	14 0.60	2 0.08	2,300 100%
	15	565 51.50	388 35.30	107 9.70	31 2.80	1 0.09	3 0.27	4 0.36	1,099 100%
	25	233 88.60	24 9.10	4 1.50	2 0.80				263 100%
D	1	2,371 72.60	579 17.73	233 6.83	70 2.14		15 0.46	8 0.24	3,266 100%
	5	1,950 74.40	339 12.90	207 7.90	64 2.44	43 1.64	8 0.30	11 0.41	2,622 100%
	13	928 57.80	409 25.50	167 10.40	74 4.60		30 1.86	3 0.18	1,611 100%
	23	791 68.50	195 16.90	85 7.40	69 6.00	5 0.43	5 0.43	4 0.34	1,154 100%
	35	1,139 58.80	570 29.40	124 6.40	91 4.70	1 0.05	14 0.72	2 0.10	1,941 100%
E	1	2,223 53.50	1,525 36.00	104 3.50	337 8.00		49 1.17	1 0.02	4,239 100%
	3	2,156 72.70	509 17.20	189 6.40	69 2.30		33 1.11	9 0.30	2,965 100%
	10	1,273 82.00	149 9.60	111 7.20	13 0.80		7 0.45		1,553 100%
	16	733 81.00	112 12.36	36 3.97	23 2.54		1 0.11	1 0.11	906 100%
	26	922 75.80	192 15.80	74 6.10	17 1.40		10 0.82	1 0.08	1,216 100%
	33	850 62.27	324 23.74	116 8.50	67 4.91		6 0.44	2 0.15	1,365 100%
F	5	577 32.00	535 29.67	621 34.44	25 1.39		28 1.55	17 0.94	1,803 100%
	15	691 55.60	252 20.30	204 16.40	35 2.80		56 4.50	9 0.72	1,247 100%
	25	682 73.57	130 14.02	101 10.90	8 0.86		2 0.22	4 0.43	927 100%

Table 4. Macrobenthic mean densities along sampling transects according to carbonate content of sediments
(kp. = kilometric point).

Transect	Locality	Mean density (ind.m^{-2})	Sediment carbonate content (%)	Mean (%)	Standard-deviation
E	kp. 14 bay	1,370	8.4-13.3	1.00	2.58
A	Aqaba beach	1,320	7.2-18.5	12.3	5.75
F	kp. 21 bay	1,170	6.3-12.3	9.3	3.15
B	kp. 8 canyon	948	5.9-10.5	8.0	2.13
D	kp.12 coral reef	920	73.8-85.6	79.9	5.91
C	kp. 8 coral reef	815	75.4-84.4	81.4	4.08

Table 5. Variations of the macro- meiobenthos ratio in the littoral sediments of the Jordan coast of the Gulf of Aqaba.

Transects	F	E	B	A	D	C
Depth (m)						
1		★1/281				
3		△1/1,989	✱1/2,395			
5	✱1/4,091				✱1/2,183	✱1/2,946
10		△1/616	✱1/17,100	△1/2,472		
13					✱1/1,983	
15	★1/995		△1/313			✱1/1,961
23					✱1/1,229	
25	△1/729		★1/1,840	△1/938		✱1/271
26		✱1/1,993				
33		✱1/1,606				
35					✱1/2,652	
means	1/1,938	1/1,297	1/5,412	1/1,705	1/2,012	1/1,726
means			1/2,668		1/1,889	

△ seagrass beds ; ★ seagrass bed vicinity ; ✱ bare sands

Table 6. Macrobenthic densities in the Indopacific "Biocenose of coarse and medium sands under bottoms currents" (= "*Asymetron lucayanum* community").

LOCATION	DENSITY (ind.m^{-2})
Tulear, Madagascar (Thomassin, 1978b)	
Barrier reef :	
outer reef slopes, fine and medium sands of the grooves or sandy basins *Urothoe serrulidactylus* assemblage	696
reef flats	480
enclosed lagoon slopes	833-2,720
Lagoonal reef :	
microatoll reef flat	7,980
Mayotte Island (Gout, pers. comm.)	
Barrier reef flats pools	2,739
Noumea, New Caledonia (Thomassin, pers. comm.)	
Barrier reef inner slope	6,081
Lagoonal bottom	1,166
Moorea Island, Polynesia (Thomassin et al., 1982)	
Deeper outer reef slope	636
Barrier reef flat	496-1,824
Fringing reef flat	2,242
Aqaba (our data)	
Fringing reef outer reef slopes, transect C	780 - 970
transect D	810 -1,200

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THE DECAPOD REPTANTIA AND STOMATOPOD CRUSTACEANS OF A TYPICAL HIGH ISLAND CORAL REEF COMPLEX IN FRENCH POLYNESIA (TIAHURA, MOOREA ISLAND): ZONATION, COMMUNITY COMPOSITION AND TROPHIC STRUCTURE

BY

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Abstract :

In a typical High Island coral reef complex of French Polynesia (transect of Tiahura, Moorea Island, Society Archipelago), 73 species of decapod Reptantia and stomatopod crustaceans were collected. Over 9 stations localised along the transect, 3 different units of hard coral substrate of similar volume (about 17 litres each), were sampled at each station. The results are discussed from two aspects : the first shows that at least 50 carcinologic species occur within the cavitary biotopes ; 16 species (mainly Xanthid crabs), represent more than 90% of all collected individuals. Most of the dominant species are widely distributed along the transect (*Chlorodiella barbata*, *Pilodius pugil*, *Liocarpilodes integerrimus*, *Galathea aculeata*), and locally, some others are numerically important (*Chlorodiella laevissima*, *Globopilumnus globosus*, *Daira perlata*, *Phymodius ungulatus*, etc.). The second aspect concerns the repartition of species in the different biotopes in relation to their feeding habits. Based on the functional morphology of chelipeds, mouth-parts and gastric mill, and on gut content analysis, the species were placed into 5 MORPHOLOGIC GROUPS : filter-suspension feeders, omnivores/herbivores, omnivores/carnivores, generalised omnivores and predators. The feeding habits and the distribution pattern of abundant species suggest that trophic and habitat partitioning may exist. The predominant species show either different nutritional modes, or inhabit different areas and/or biotopes. Distribution patterns of the morphologic groups in the different substrates are proposed, and schemes of interspecific relations are analysed.

INTRODUCTION.

In French Polynesia, studies concerning the carcinologic fauna have essentially dealt with systematics and biogeography of the decapod Reptantia (Jacquinot & Lucas, 1853 ; Milne-Edwards, 1861-1904 ; Forest & Guinot, 1961, 1962 ; Serène, 1972 ; Yaldwin, 1972 ; Griffin & Yaldwin, 1977). The few biological and ecological studies on these crustaceans are limited to commercial and edible species (Guinot, 1967 George, 1972, 1974), as well as to species associated to madreporian corals (Kropp & Birkeland, 1981; Odinetz, 1983).

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The transect of Tiahura (Moorea Island), is a typical High Island coral reef complex (Salvat, et al., 1972). As such, many studies have been carried out there (Anonymous, 1977). However, the only ecological research on decapod crustaceans deals with species of the cryptofauna (Peyrot-Clausade, 1977b ; Monteforte, 1984a,b), the "petite faune" associated to algae (Naim, 1980a), and the crustaceans associated with pocilloporid corals (Odinetz, 1983).

In Tiahura, although crustaceans do not account for as large a number of species as molluscs and fishes, their relative abundance must not be underestimated : Odum & Odum (1955), and Hiatt & Strasburg (1960), pointed out that crustaceans represent a very important link in the energy transfer from producers and low-level consumers to higher consumers in coral reefs, and the larval input of these species to the water is also known to be very rich.

The importance of cavitary crustaceans in coral reefs has been studied by Garth (1974) and Peyrot-Clausade (1977a,b), but their trophic role within benthic communities is not well known. Feeding habits of crustaceans have been studied from morphologic and/or empirical observations (Orton, 1927 ; Nicol, 1932 ; Schafer, 1954 ; Ebling, et al., 1964 ; Muntz, et al., 1975 ; Warner, 1977 Zipser & Vermeij, 1978 ; Kunze & Anderson, 1979 ; Kropp, 1981 ; Rheinallt & Hughes, 1985 ; Rheinallt, 1986 ; Skilleter & Anderson, 1986). Works on trophic relations in nature are few and isolated ; most of them studied the crustaceans associated with sabellariid reefs (Rivosecchi, 1967 in Italy; Fausto-Filho & Furtado, 1970 in Brasil ; Gruet, 1970, 1971 in the North of France ; Gore, et al., 1978 in Florida). For French Polynesia, our work is the first approach to this subject. We have studied the distribution of crustacean species in the reef of Tiahura (Moorea Island) in relation to their different feeding habits. Species include those strictly inhabiting the hard substrates (living and dead corals), and other species either facultatively inhabiting these substrates or endogenous to sand substrates.

THE STUDY AREA.

The transect of Tiahura is located at the Northwest coast of Moorea Island (Fig. 1A). This area, "a typical High-Island coral reef complex" (Salvat, et al., 1972), is divided into three sections (Fig. 1B). From the beach towards the reef front (800 m long), these are :

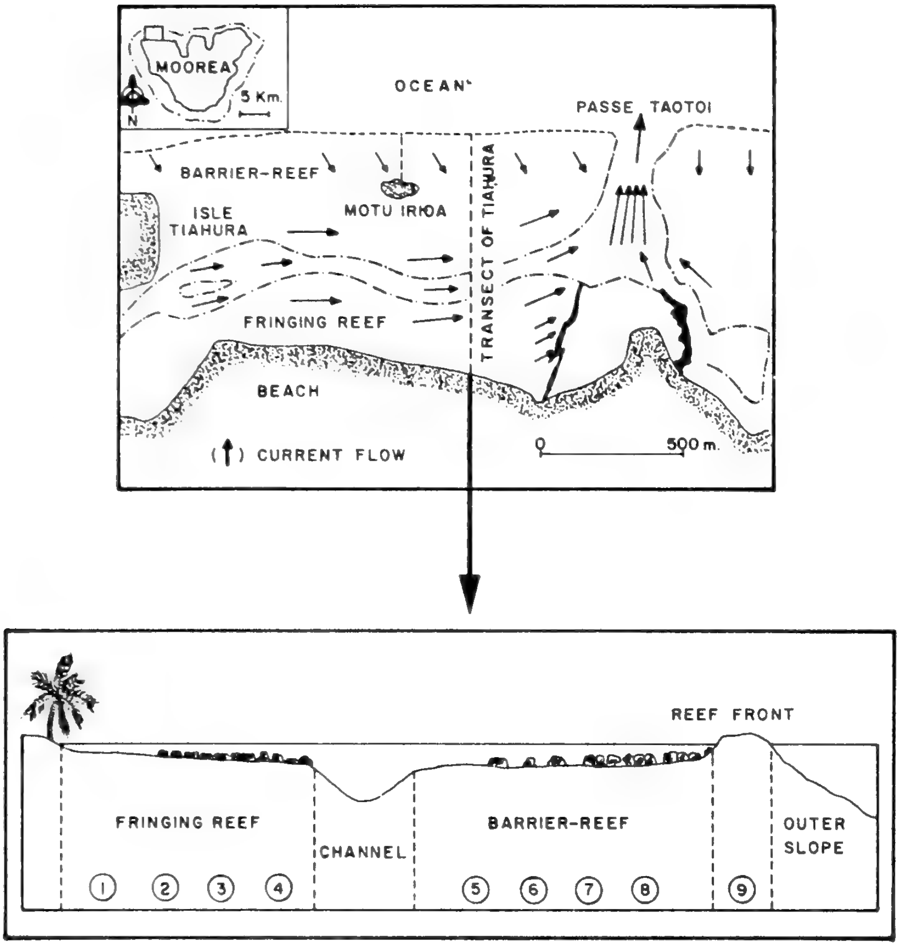

Fig. 1.- Localization of the study area.-

1A : Position of the transect of Tiahura in Moorea Island and general aspect of the area.

1B : Distribution of the sampling stations along the transect of Tiahura.

- the fringing reef (250 m long and 0.20 m to 0.50 m average depth, and 2 m on the channel margin).
- the channel (50 m long, 10 to 13 m depth).
- the barrier-reef (500 m long, 1.5 to 2.50 m depth near the channel, and 0.50 m depth around the reef front).

A) The Fringing Reef.

Soft substrates (sand sediments) and debris are dominant in the fringing reef. Towards the channel, living coral colonies become abundant (*Psammocora*, *Synarea*), and they form huge coral heads at the margins of the channel (Fig. 2).

Hard substrates are mainly represented by *Psammocora*, *Pavona cactus* and *Synarea*, and dead coral colonies, which here cover a larger area than living corals. Dead coral provides an optimum environment for algal colonization : algae cover a large proportion of the fringing reef in Tiahura (Fig. 2).

B) The Channel.

The bottom of this channel is constituted almost totally of sand sediments (Fig. 2). This zone is under the constant influence of a strong current flowing parallel to the coast (Fig. 1A). The only benthic species inhabiting it are endogenous (*Conus spp.*, polychaetes, Thallassinidae).

C) The Barrier-reef.

Scattered coral heads are situated on the outer margins of the channel. Towards the reef front, there is a gradual increase of coral colonies. Living coral colonies are more abundant than in the fringing reef, therefore algal colonisation is less here than in the former reef section (Fig. 2). *Pavona cactus*, *Montipora*, *Porites* and *Acropora* are well represented.

The reef front is constituted by a ridge of calcareous algae which, together with encrusting corals, provides a well developed cavitary biotope thoroughly colonized by the cryptofauna.

MATERIALS AND METHODS.

Nine stations were established along the transect of Tiahura (Fig. 1B). A total of 50 liters of hard substrate was sampled by SCUBA diving at each station, 1/3 of which was composed by dead corals and the other 2/3 of living

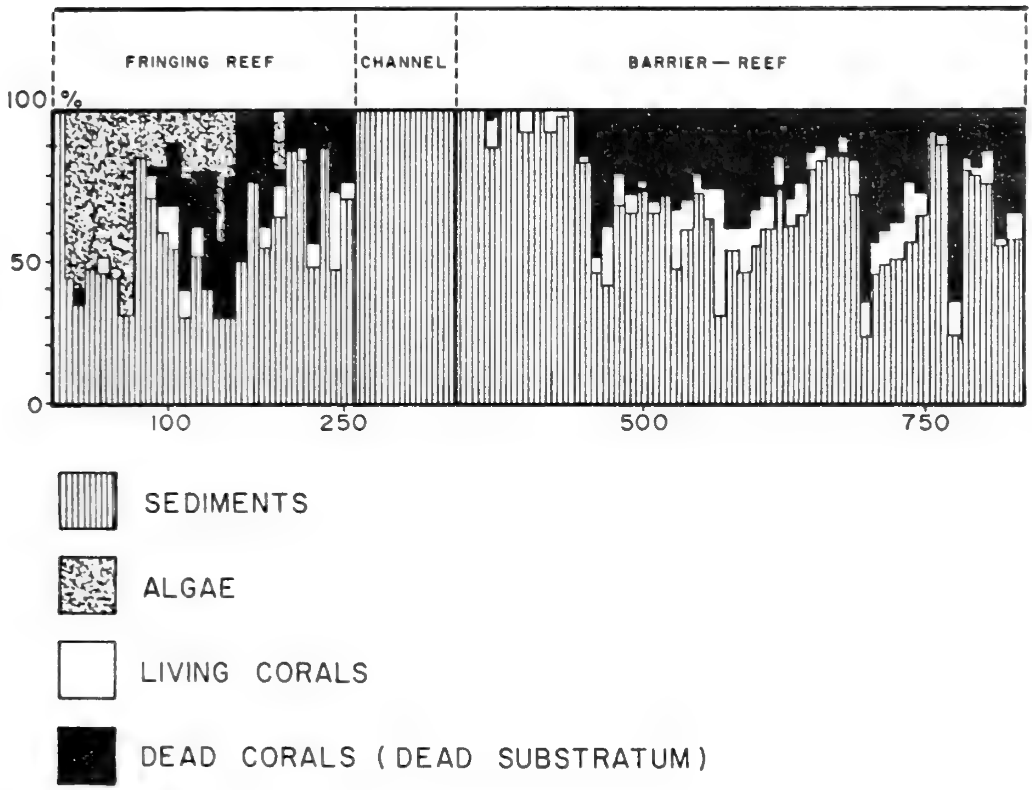

Fig. 2.- Distribution and relative covering area of the principal types of biotopes in the transect of Tiahura.

corals.

The coral colony (dead or alive) to be sampled was selected by its size (all units sampled were similar in volume), its architecture (relatively regular geometric shapes and presence of a complex cavitary network), and its representativeness in the sampling station.

On the fringing reef, dead substrate and living coral colonies of *Pavona cactus* and *Psammocora* were sampled at each station. On the barrier-reef, dead substrate and living coral colonies of *Pavona cactus*, *Montipora* and *Porites* were taken.

The selected colony was covered in situ with a plastic bag (25x35 cm) in order to avoid the escape of the cavitary fauna. The colony was then detached from the substrate and the bag was closed immediately. The area around was surveyed, and some large and/or non-strictly cavitary species were captured by hand and also counted. However, the abundance of these species may have been underestimated, either because of difficulty in localizing the individuals (endogenous species), their facility to escape (swimming crabs), or their habit of forming aggregates (pagurid crabs : Ball, 1950 ; Ball & Haig, 1974 ; Hazlett, 1974).

Large-sized nocturnal species (very rare), those captured at the outer slope, and large semi terrestrial species (*Coenobita perlatus* and *Cardisoma carnifex*, both very abundant), were not included in the counts.

Determination of the feeding habits of the crustacean fauna in this study was based upon observation of the functional morphology of chelipeds, mouth-parts and gastric mill. Gut content analyses were also accomplished, but they were merely qualitative because of the small size of most of the individuals (< 20 mm width), and the deficient state of conservation of the collection after 3 months of storage and transport (Polynesia-Paris). Nevertheless, the information thus obtained was very useful for defining 5 MORPHOLOGIC GROUPS of species, related to their alimentary preferences.

RESULTS.

A) Specific Richness.

A total of 73 species of decapod Reptantia and stomatopod crustaceans was identified at the transect of Tiahura, xanthid crabs being largely dominant (Tab. 1). Compared with a total of 140 species collected during our

whole mission in French Polynesia (Moorea, Tahiti, Takapoto, Makatea and Mataiva), the observed specific richness of Tiahura was quite high : 52% of total collected species, 18% of which were "endemic". This comparison seems to confirm the representativeness of the transect of Tiahura as a typical High Island coral reef complex (Salvat, et al., 1972 ; Monteforte, 1984a,b).

Twenty-eight species were collected on the fringing reef, 10 on the barrier-reef, 19 on the reef front (some of them appeared also on the outer slope), and 16 species were founded both on the fringing reef and the barrier-reef. Several of these last were numerically dominant along the transect.

B) Qualitative Distribution and Relative Abundance.

A total of 2500 individuals was captured in the transect of Tiahura, hand captures included (Tab. 1). Four species accounted for more than 75% of the total : *Chlorodiella barbata*, *Pilodius pugil*, *Galathea aculeata* and *Liocarpilodes integerrimus*. These, with 12 additional species, accounted for about 95% of the total collected individuals. The 16 speciescharacterize the carcinologic fauna of Tiahura (Peyrot-Clausade, 1977b ; Monteforte, 1984a,b). The most numerically important of these species are *Chlorodiella laevissima* (barrier-reef), *Liomera bella* (wide distribution), *Phymodius ungulatus* (fringing reef), *Actaea cavipes* (wide distribution), *Chlorodiella cytherea* (wide distribution)(Fig. 3).

The 4 dominant species over the transect are widely distributed, except on the reef front (Fig. 3). In fact, the 12 species following in abundance are those that primarily define the differences between the crustacean communities of the fringing reef, the barrier-reef, and the reef front. This last area presents a characteristic arrangement of species, some of them appearing not very far back towards the lagoon area of the transect, but oftenly to 6 m depth on the outer slope.

C) The Feeding Habits.

Decapod crustaceans are primary and secondary consumers : filter-suspension feeders, omnivores and predators. The limits of these divisions are not well defined because of the various feeding habits (Gordon, 1964 ; Warner, 1977). However, the functional morphology of alimentary body structures has a close relationship with the kind of food utilized by the species and feeding behaviour (Dahl, 1952 ; Schafer, 1954 ; Bovbjerg, 1960 ; Bakus, 1975 ; Caine, 1975 ; Warner, 1977). Observation of

Tab. 1.- List of decapod Reptantia and stomatopod species: Numerical abundance of individuals collected in each station at the transect of Tiahura (Moorea).
OSL : Outer Slope.
TOT : Total transect.

	STATIONS										
SPECIES	1	2	3	4	5	6	7	8	9	OSL	TOT
STOMATOPODA											
Gonodactylus espinosus		7	6	4		3	3	2			25
Gonodactylus viridis		2	2	2	2	3	2	2			15
PAGURIDAE											
Aniculus aniculus									5		5
Calcinus gaimardi										1	1
Calcinus laevimanus	3	9									12
Calcinus latens	6	12									18
Calcinus sp.1		2									2
Calcinus sp.2		1	1								2
Calcinus sp.3				1							
Dardanus gemmatus			1							1	2
Dardanus lagopodes							1			1	2
Pagurixus sp.										1	1
Trizopagurus strigatus									1	1	2
GALATHEIDAE											
Galathea aculeata	13	79	53	24	22	77	54	18	13		353
PORCELLANIDAE											
Petrolisthes sp.1	1	1									2
Petrolisthes sp.2		2									2
Petrolisthes sp.3								2			2
Petrolishtes sp.4									3		3
Petrolisthes sp.5								1			1
Petrolisthes sp.6								1			1
Petrolisthes sp.7								1			1
Pachycheles sp.									2		2
HIPPIDAE											
Hippa sp.	2										2
CALAPPIDAE											
Calappa hepatica		2	3	2							8
PORTUNIDAE											
Carupa tenuipes									12		12
Portunus granulatus			3								3
Thalamita admete		3	3	1		1	2	4			14
Thalamita crenata		1	3	1	1	2	2	1			11
Thalamita pilumnoides		1	4			6	9				20
XANTHIDAE											
Actaea cavipes	1	8	2			9	14	1			35
Actaea sp.		1	2	1							4
Actaeodes hirsutissima		6	10	3							19
Atergatis floridus		6	11								17

Tab. 1 (cont.).

SPECIES	1	2	3	4	5	6	7	8	9	OSL	TOT
						STATIONS					
Atergatopsis cf. germaini								1		1	
Chlorodiella barbata	4	232	196	54	20	28	30		1		564
Chlorodiella cytherea		5	8				13	8			34
Chlorodiella laevissima							61	14	12	5	92
Chlorodiella nigra		13	7								20
Daira perlata								10	6	5	18
Etisus anaglyptus									1	1	2
Etisus dentatus			3	1							4
Euxanthus exsculptus										1	1
Globopilumnus globosus								2	28	5	35
Lachnopodus bidentatus								1	3		4
Lachnopodus subacutus								1	2		3
Leptodius sanguineus	2	5									7
Liocarpilodes integerrimus			9	5	38	135	123	15	21		346
Liomera bella		24	20	7		2	2				55
Liomera rubra							1				1
Liomera rugata		1	1				1				3
Lioxanthodes alcocki								5	18		23
Lophozozymus edwardsii									1	1	2
Lophozozymus dodone			2								2
Lophozozymus glaber							3				3
Lybia tesselata		1									1
Medaeus noelensis								3	3	2	8
Paractaea retusa									10		10
Paraxanthias notatus								15	6		21
Phymodius monticulosus		18	9								27
Phymodius nitidus									12	1	13
Phymodius ungulatus		20	28	1							49
Pilodius pugil	2	96	162	41	22	67	32				422
Pilodius scabriculus		9	3	2	2		5	2			23
Pilumnus sp.1							2				2
Psaumis cavipes	2	3	1	4	4	2	2	6	8	1	31
Pseudoliomera variolosa									2		2
Xanthias lamarcki		9	2		1	6	1	1			20
Xanthias latifrons									6		6
GRAPSIDAE											
Pachygrapsus minutus	3	5									8
Pachygrapsus plicatus	2										2

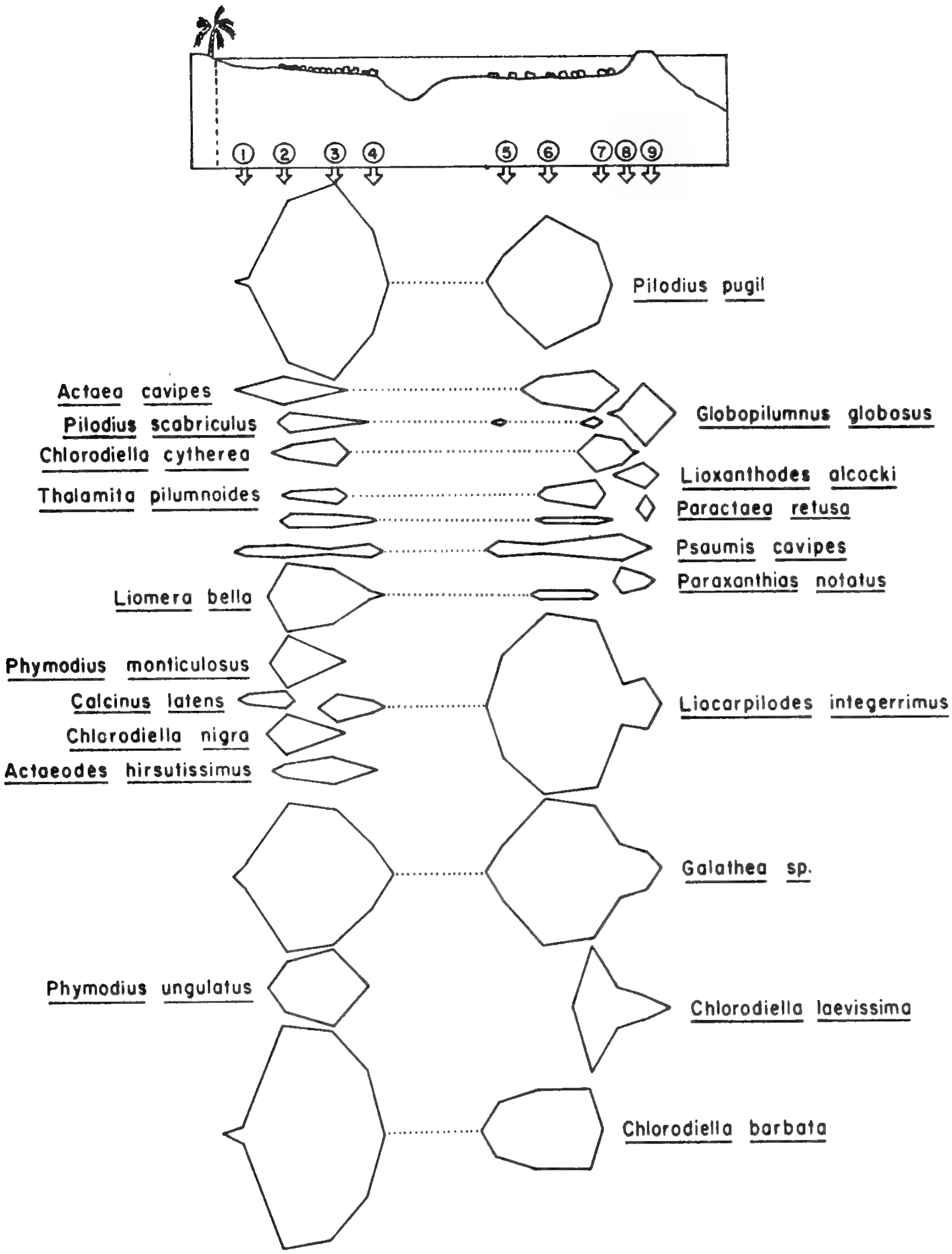

Fig. 3.- Zonation and relative abundance of the principal Decapod Reptantia collected in the transect of Tiahura (only species collected in hard substrates).

these structures was a criterion for placement of a particular specie into one or another of the 5 MORPHOLOGIC GROUPS defined in our study. Other criteria were : in situ observations, gut content analysis, and other studies on morphologically similar species. The groups are: filter-suspension or direct bottom-deposit feeders, omnivores/herbivores, omnivores/carnivores, generalized omnivores and predators.

C.1) Filter-suspension or Direct Bottom-deposit Feeders.

Species of this group belong essentially to the families Galatheidae (*Galathea aculeata*) and Porcellanidae (*Petrolisthes spp.*), which agrees with other principal works (Nicol, 1932 ; Knudsen, 1964 ; Caine, 1975 ; Gore, et al., 1978 ; Kropp, 1981).

These species show flat and slender chelipeds. The fingers are long and acute with their internal margins often finely dentate. On the ventral surface of the fixed fingers there is a row of fine sharp-pointed spines which sometimes serve actively when the animal obtains food by rasping the substrate (Nicol, 1932 ; Caine, 1975).

The 3rd. pair of maxillipeds is very important. These are extremely mobile structures bearing long and relatively stiff setae at their distal margin which function as a net to trap suspended particles or to sweep the bottom directly (Fig. 4). These setae are cleaned by the 2nd. and 1st. pair of maxillipeds which then bring the food to the mouth (Nicol, 1932 ; Kropp, 1981).

At the interior of the endostome there is a pair of well-calcified mandibles. In *Galathea aculeata* and *Petrolisthes spp*. collected at Tiahura, teeth with finely tuberculated surfaces were observed on these mandibles. The structure of the gastric mill, although difficult to appreciate, seems to show finely dentate masticatory ossicles with soft setae at their margins. These features are commonly found in species feeding upon small and rather soft particles (Caine, 1975). In addition, these individuals are very small (*Galathea aculeata* : 5 to 7 mm total length, and *Petrolisthes spp*. <5 mm width), which suggests that their food consists of such fine material as plankton, phytobenthos, larval forms and detritus. Unfortunately, identification of gut contents was not possible, so the degree of alimentary selectivity for these species is unknown to us.

Eight species of this morphologic group were found at Tiahura, accounting for 17% of total individuals in the

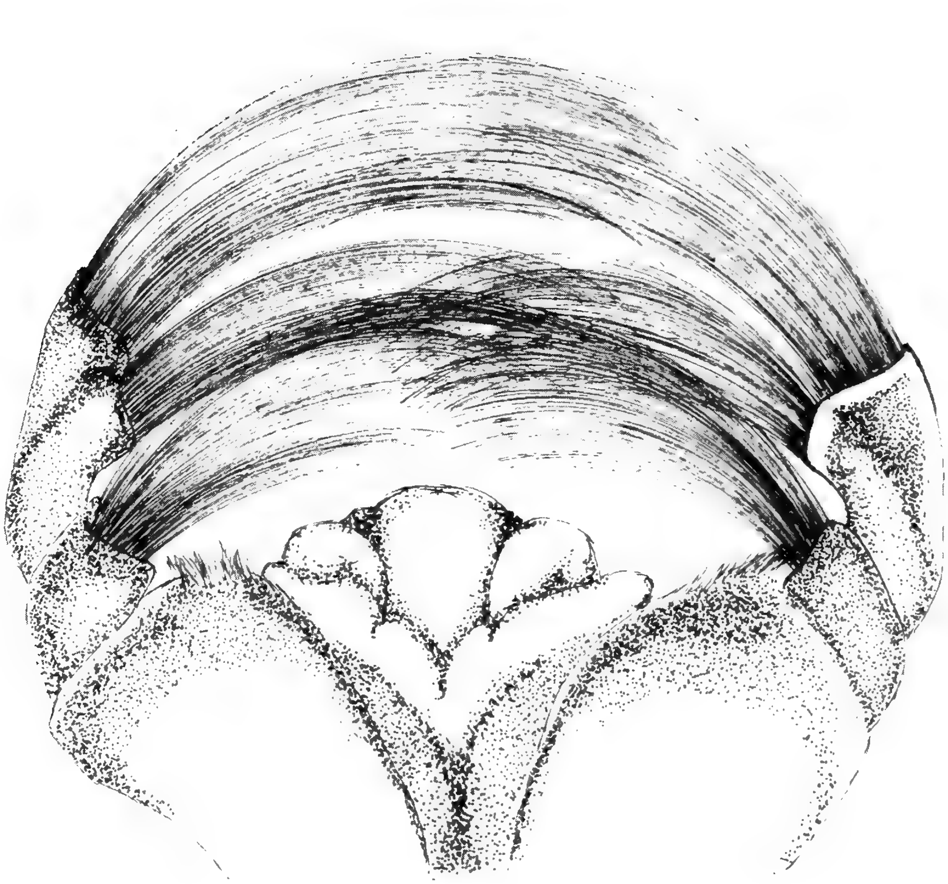

Fig. 4.- Group of filter-suspension or direct bottom-deposit feeders : 3rd. pair of maxillipeds of Petrolisthes sp. (ventral view).

transect (Tab. 2). One species was largely dominant, Galathea aculeata, which represents about 15% ; the other 2% was shared among 7 species of Petrolisthes.

On the fringing reef, filter-suspension feeders represented 13% of total individuals. On the barrier-reef, this group was comparatively more important : 25% of total individuals (Tab. 2).

C.2) Omnivorous Species.

These species are able to exploit a large biotope, their alimentary resources being very diversified : algae, small cavitary species as polychaetes, sponges, echinoderms, molluscs, other crustaceans, as well as disintegrated organic material and carrion.

The morphology of chelipeds is one of the principal bases utilized to classify the omnivorous species, although the morphology of the gastric mill, size of species and gut contents are also registered. Some main features of the chelipeds are relevant :

1) Chelipeds are more or less voluminous, straight or somewhat concave.
2) Internal margins of fingers :
   - with cutting edges.
   - with tuberculate surfaces (dentiform processes).
3) The claws, once closed :
   - leave a wide space between fingers (non-joined claws).
   - close almost perfectly (joined claws).
4) The fingertips are :
   - pointed or slightly blunt.
   - excavated as a well-defined hoof.

These characteristics are not present separately in a particular species, but oftenly occur in combination. There are species having similar chelipeds in size and form (homochelia), or species with different chelipeds (heterochelia). The morphology of dentary surfaces may also be similar in both chelipeds (homodontia), or different (heterodontia) (Schafer, 1954).

From the distribution of these morphologic characteristics in a particular species, it was possible to deduce habitual food type very closely, and the methods utilized to obtain it. Upon the bases of these observations, 3 MORPHOLOGIC GROUPS of omnivorous species were constituted : omnivores/herbivores, omnivores/carnivores, and generalized omnivores. We must recall that these divisions are not strict : a single species showing wide

distribution in the transect could present more generalised or more restricted feeding habits depending on the resources available, the biological cycle (of the species itself or of the organisms composing its food resource), or on the presence of a competitor (Gore, et al., 1978).

C.2.1) Omnivores/herbivores.

Species representing this group are *Chlorodiella barbata*, *C.nigra*, *C.cytherea*, *C.laevissima*, *Phymodius ungulatus*, *P.monticulosus*, *Pilodius pugil*, *P.scabriculus* and *Lioxanthodes alcocki*.

The chelipeds of these species are rather straight and not very massive. Fingers are slender and eventually show 2 or 3 well-developed molariform teeth at their inner margins, but the rest of the dentary surfaces are smooth. The claws are non-joined. The fingertips are excavated forming a hoof-like structure, generally well defined (Fig. 5). This lastcharacteristic is commonly found in crabs having preferentially herbivorous feeding habits (Crane, 1947; Knudsen, 1960, 1964; Griffin, 1971 ; Warner, 1977). It is in fact a structure very well adapted to cut out laminar pieces from algae (Forest, pers. comm., 1984 pers.obs.), or to spoon encrusting material from the substrate (Skilleter & Anderson, 1986).

Homochelia is common in some species (*Chlorodiella spp.*, *Phymodius spp.*), but sometimes a slight heterochelia is present (*Pilodius spp.*, *Lioxanthodes alcocki*). Homodontia is also common in this group.

The particular structure of the gastric mill (finely tuberculate masticatory surfaces, blunt ossicles with abundant setae), suggests that these species utilize food particles not requiring extensive grinding. Moreover, in the gut contents there were apparently no fragments of mollusc shells, but algal material seemed to predominate. The size of these species is small, rarely over 10 mm width.

A total of 17 species of the transect of Tiahura were included in this assemblage, or 24% of total species richness. The relative abundance of this group was about 59% of total individuals in the transect ; it was the dominant group, where *Chlorodiella barbata* and *Pilodius pugil* accounted for more than 35%.

In the fringing reef, 11 species represented 74% of total individuals in this sector. *C.barbata* and *P.pugil* were the dominant species, but there was also an abundant group of species such as *Chlorodiella nigra*, *Phymodius*

Fig. 5.- Group of omnivore/herbivore species : Right cheliped of Chlorodiella nigra (Xanthidae). Non-joined claw with hoofed fingertips.

ungulatus, *Phymodius nitidus*, *Pilodius scabriculus*, etc. (Fig. 3, Tab. 2).

For the reef flat of the barrier-reef, *C.barbata* and *P.pugil* were still abundant, being gradually replaced towards the reef front by *Chlorodiella laevissima* which then became one of the dominant species. In total for the barrier-reef, 17 species of this group accounted for 38% of total individuals.

C.2.2) Omnivores/carnivores.

The chelipeds of species included in this group are generally massive and straight, although they may be slightly concave in some small-sized species (*Liomera spp.*, *Psaumis cavipes*, *Xanthias lamarcki*). The fingers are short and quite strong, bearing tuberculate, cutting, or tuberculate-cutting dentary surfaces, generally well-developed. The fingertips are pointed or lightly rounded. The claws are joined (Fig. 6). Homochelia and homodontia are common (*Xanthias lamarcki*, *Liomera spp.*, *Actaeodes hirsutissima*, *Psaumis cavipes*, *Daira perlata*). Ill-marked heterochelia also exists (*Leptodius sanguineus*), but when differences exist, these are very evident (*Pilumnus spp.*, *Paraxanthias notatus*, *Globopilumnus globosus*, *Liocarpilodes integerrimus*). This combination of structures, and mainly the presence of protuberant teeth over the internal margins of fingers, characterize the crabs having a preferentially carnivorous alimentary regime (Schafer, 1954 ; Knudsen, 1964 ; Vermeij, 1977a ; Warner, 1977 ; Zipser & Vermeij, 1978).

Polychaetes and small molluscs surely constitute a very important part of their diet, as shown by the gut content analysis in which fragments of shells, opercules and mandibules of polychaetes were often found. The structure of chelipeds and fingers is efficient for the manipulation of hard and voluminous objects and for tearing off soft tissues from shells (Warner, 1977 ; Skilleter & Anderson, 1986). The gastric mill is much more massive than in that of herbivorous species, having the masticatory ossicles edged with fine but sharp spines, well-developed grinding surfaces, and few setae.

There were 28 species of this group in Tiahura, or 39% of total species richness. Their relative abundance was estimated in 18% of total individuals.

In the fringing reef, 13 species composed 7% of total individuals, where *Liomera bella* and *Actaeodes hirsutissima* accounted for 5%).

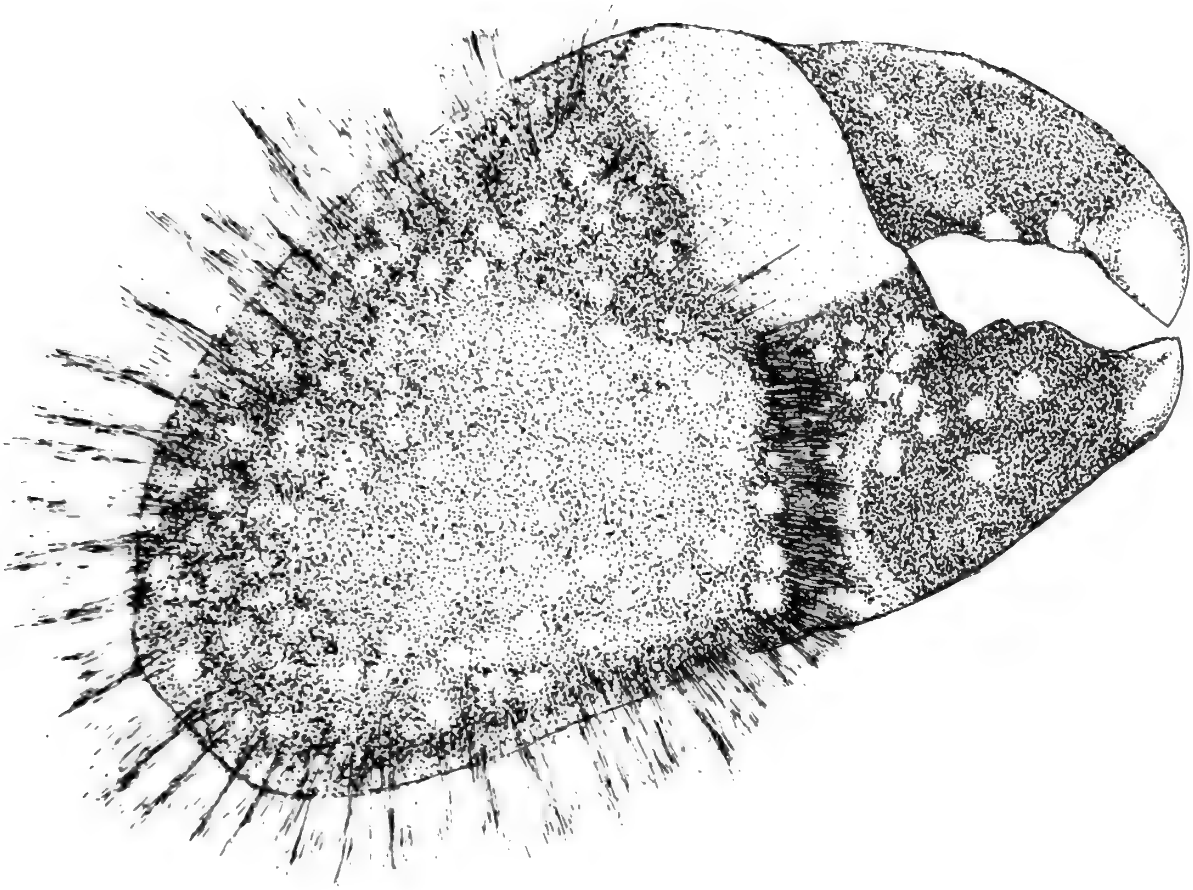

Fig. 6.- Group of carnivore/herbivore species : Right cheliped of Globopilumnus globosus (Xanthidae), a facultative malacophage crab.

For the barrier-reef, 21 species were proportionally more important : 33% of total individuals in this sector. Liocarpilodes integerrimus were numerically dominant within this group (25% of total individual for the barrier-reef). However, this species was gradually replaced by a group of abundant omnivore/carnivore species towards the reef front (Globopilumnus globosus, Paraxanthias notatus, Daira perlata).

C.2.3) Generalized Omnivores.

Several authors consider as generalized omnivores the crabs of the family Grapsidae (Bacon, 1971 ; Griffin, 1971 ; Gore, et al., 1978), and those of the superfamily Paguridea (Orton,1927 ; Samuelson, 1970 ; Hazlett, 1974 ; Caine, 1975). However, some species may behave as predators (Vermeij, 1978), or even as corallivores (Glynn & Stewart, 1972 ; Glynn, 1973).

In the Grapsid species collected at Tiahura (Pachygrapsus minutus, P.plicatus, both being small-sized of some 5 mm width), the chelipeds are small and straight. The internal margins of fingers show cutting or finely serrated surfaces without prominent molariform tubercules. The fingertips are pointed. Heterochelia and heterodontia are weakly pronounced, the chelipeds being relatively similar. The claws are joined (space between fingers is narrow).

Concerning the pagurid crabs, their chelipeds have two functions : they are auxiliary in the alimentary activities, and play the role of an opercle for species inhabiting gastropod shells. Heterochelia and heterodontia are therefore strongly pronounced. However, although the structure of fingers is adapted to this living style, their internal margins do not bear protuberant tubercles, these surfaces being for cutting or finely serrated.

The food resources of generalized omnivore species are very diversified. They can actually use all kinds of detritus and organic debris, carrion, urban residues, etc., and although this morphologic group was represented at Tiahura by 11 species (15% of total species richness), numerically, they were very few (2% of total individuals in the transect). On the fringing reef this group comprises 3% of individuals. Pachygrapsus minutus (Grapsidae) and Calcinus latens (Paguridae) were practically the only numerically important species. In the barrier-reef this group was absent.

C.3) Predacious/carnivores.

Some omnivore/carnivore species may be able to behave as predacious, provided that they have a large adult size (over 30 mm width), massive subequal claws with sharp-pointed fingers, well developed molariform teeth on the internal margin of fingers, and the presence of a particulary prominent tooth situated in proximal position over the dactylus, generally on the major cheliped. These caracteristics distinguish the predacious malacophage crabs (Schafer, 1954 ; Crane, 1947 ; Reynolds & Reynolds, 1977 ; Vermeij, 1977 ; Warner, 1977).

Other well-known predacious species are the Portunidae (Schafer, 1954 ; Muntz, et al., 1965 ; Ropes, 1968 ; Hamilton, 1976 ; Warner, 1977 ; Rehinallt, 1985, 1986), the Calappidae (Shoup, 1968 ; Warner, 1977 ; Vermeij, 1978), and the stomatopods (Burrows, 1969 ; Caldwell & Dingle, 1975). These species are mainly specialized malacophages (Calappidae) and sometimes piscivores (portunids and stomatopods) (Figs. 7, 8).

Seven predacious species were considered in Tihaura (10% of total species). The omnivores/carnivores showing facultative predacious habits were not counted for this group.

Almost all of these species are widely distributed in the transect, except Calappa hepatica (endogenous species, fringing reef), and Carupa tenuipes (cavitary Portunidae of the reef front).

The total relative abundance of this group was estimated as 4%. For the fringing reef, 3% of total individuals found in this sector belong to the present group ; for the barrier-reef they accounted for 5% of the individuals of this sector. The most abundant species on both areas were Gonodactylus viridis and G.espinosus, two cavitary stomatopods observed only in Pavona cactus (High Islands) (Monteforte, 1984a).

Although the abundance of free-living species (Thalamita admete, T.crenata, Portunus granulatus), and that of endogenous species (Calappa hepatica), may have been underestimated because of the various capture problems, it seems that predacious crabs play only an inferior role in the trophic network of a High Island reef complex. In this type of system, the higher trophic levels seem to be occupied mainly by carnivorous fishes which are much more efficient than crabs (Perès & Picard, 1969 ; Vivien & Peyrot-Clausade, 1974 ; Galzin, 1977b ; Harmelin-Vivien, 1981).

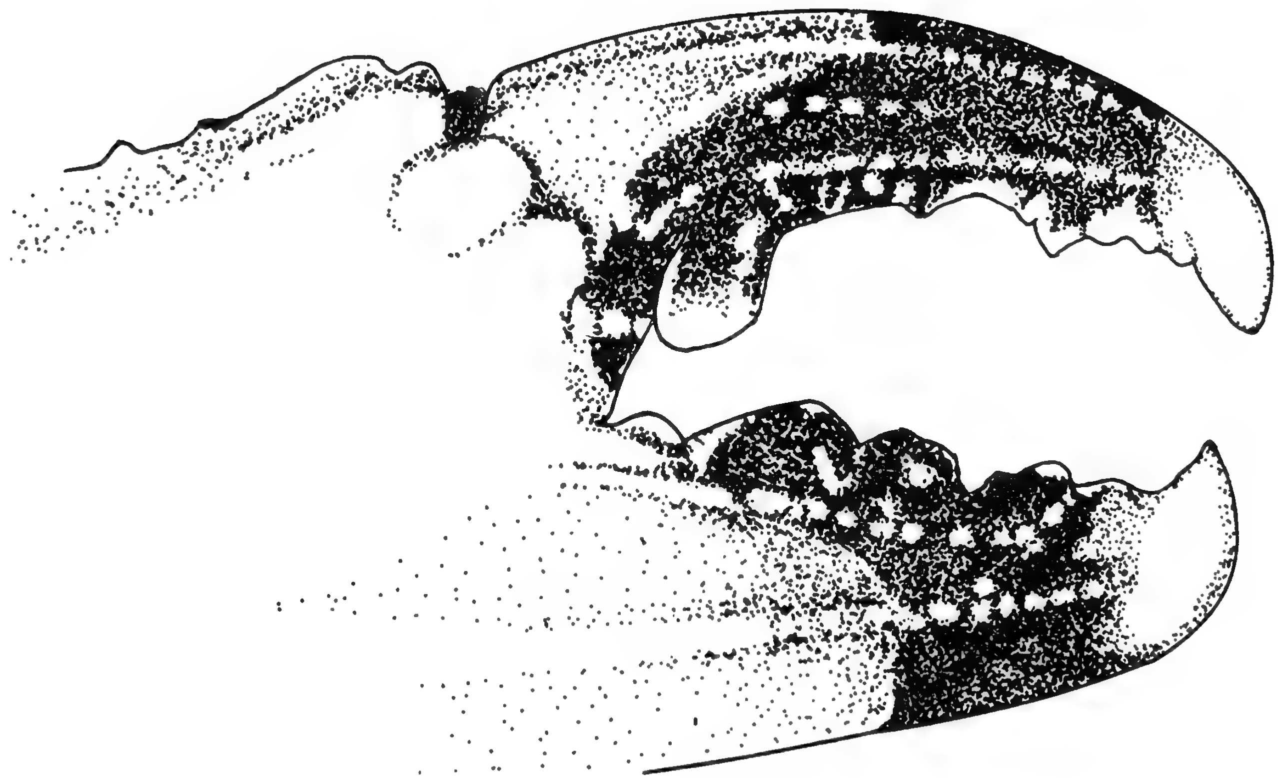

Fig. 7.- Group of predacious/carnivore species : Right cheliped of Thalamita admete (Portunidae). A fast-cutting chela with the "malacophage tooth".

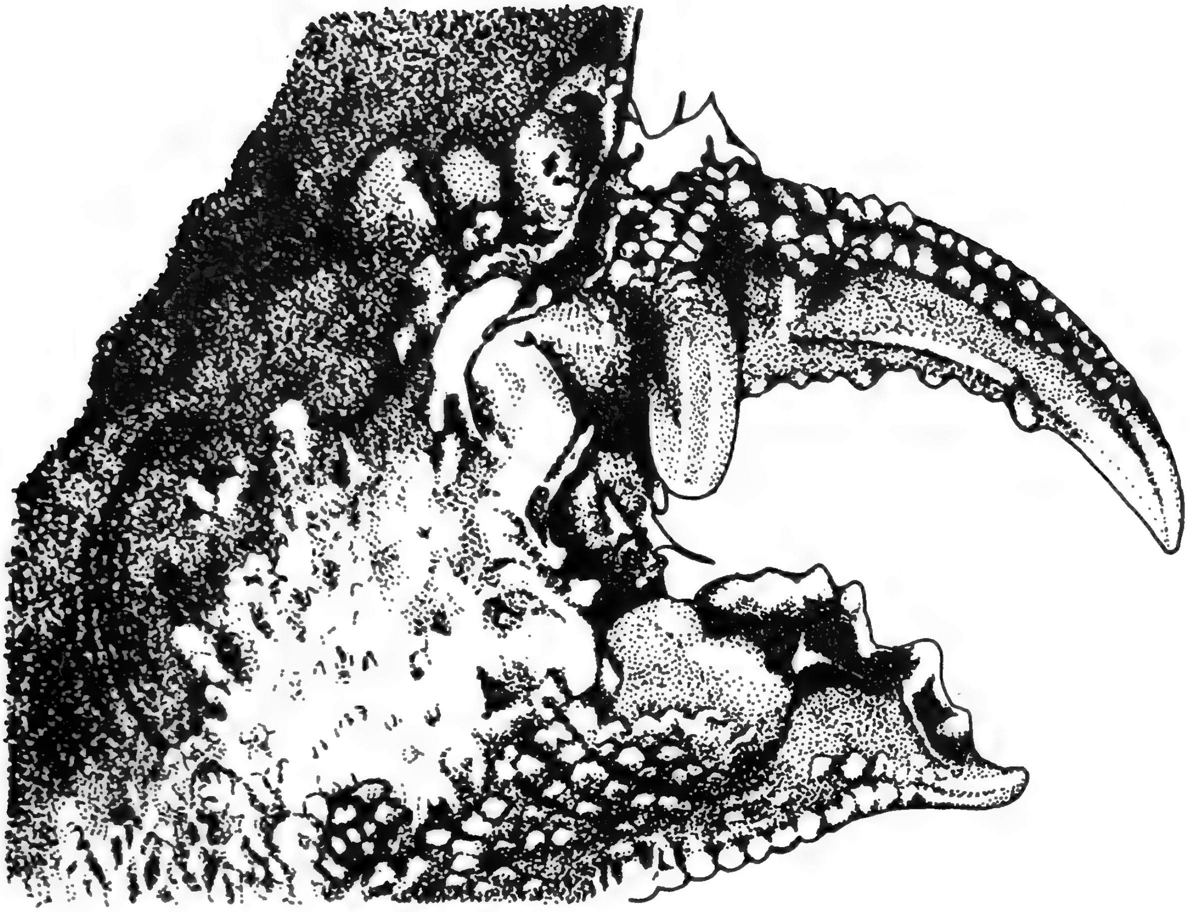

Fig. 8.- Group of predacious/carnivore species : Right (major) cheliped of Calappa hepatica (Calappidae). A typical crushing chela of a specialized malacophage crab.

Other alimentary habits important to mention are those represented by decapod crustaceans obligatorily associated with pocilloporid corals (Trapezia spp.) which are morphologically adapted to feed upon corallian mucus (Odinetz, 1983), by corallivorous pagurid crabs (Aniculus aniculus, Trizopagurus strigatus), and by pinnotherid crabs and the portunid Lissocarcinus orbicularis, respectively commensal with bivalves and holoturians.

D) Distribution of Morphologic Groups in the Substrates.

Living substrates seem to contain the majority (52%) of all collected individuals. However, each coral species is colonized differently. Pavona cactus and Psammocora are preferentially occupied (21% and 19% respectively, of total individuals), then Montipora (8%), and finally Porites (3%). Dead substrate is also highly colonized by cavitary crustaceans (44% of total individuals). The remaining 4% correspond to individuals captured by hand (Tab. 2, Fig. 9).

In pocilloporid corals, Odinetz (1983) found abundant populations of non-associated brachyuran and anomuran crustaceans. Comparing these data of abundance of non-associated crabs/volume of the coral colony with those of our study, Pocillopora and Psammocora seem to be similarly colonized by cavitary crustaceans. Nevertheless, Pavona cactus is the living coral colony that gathers the most abundant cavitary populations, which is a direct consequence of its architectural complexity.

D.1) The Fringing Reef.

The omnivore/herbivore species are dominant in all substrates (Tab. 2, Fig. 10). Within this group, Chlorodiella barbata (the dominant specie), shows affinities for dead substrates. On the contrary, Pilodius pugil (next in abundance), is more abundant in Psammocora.

Filter/suspension feeders (Galathea aculeata is the only numerically important one), show a light affinity for dead substrate (39% of total individuals of this group for the fringing reef) (Tab. 2, Fig. 10). The few exemples of Petrolisthes spp. were all collected in this substrate. Concerning the living colonies, Galathea aculeata showed noticeable preferences for Psammocora (34%), being less abundant in Pavona cactus (26%) (Fig. 10). It is possible that the swimming ability of this specie enables it to frequent the extracavitary biotopes so as to reduce the competition with corals and other benthic filter-feeders.

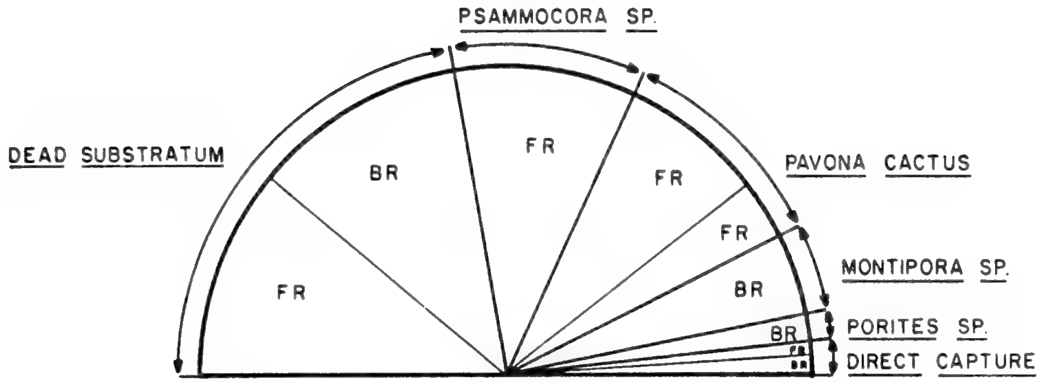

Fig. 9.- Relative abundance of individuals collected in different substrates sampled in each sector of the reef in Tiahura.

FR : Fringing reef.
BR : Barrier-reef.

Tab. 2.- Relative abundance of morphologic groups in different substrates sampled in each reef sector of the transect of Tiahura (see Fig. 10 for reference).
FR : Fringing reef.
BR : Barrier-reef.
TT : Total transect.

		CAPTURES NUMERIC ABUNDANCE			RELATIVE ABUNDANCE OF INDIVIDUALS			RELATIVE ABUNDANCE OF MORPH. GROUPS		
MORPHOLOGIC GROUPS	SUBSTRATES	FR	BR	TT	FR	BR	TT	FR	BR	TT
	Dead subst.	71	132	203	4.9	12.5	8.1	39.2	50.6	45.9
	Psammocora	62		62	4.3		2.5	34.3		14.0
FILTER-SUSPENSION	P.cactus	48	42	90	3.3	4.0	3.6	26.5	16.1	20.4
	Montipora		65	65		6.2	2.6		24.9	14.7
	Porites		22	22		2.1	0.9		8.4	5.0
	TOTAL	181	261	442	12.5	24.8	17.6	40.9	59.0	100.-
	Dead subst.	388	212	600	26.7	20.1	23.9	36.0	53.7	40.7
	Psammocora	386		386	26.6		15.4	35.8		26.2
OMNIVORES/HERBIV.	P.cactus	303	57	360	20.9	5.4	14.3	28.1	14.4	24.4
	Montipora		105	105		10.0	4.2		26.6	7.1
	Porites		21	21		2.0	0.8		5.3	1.4
	TOTAL	1077	395	1472	74.2	37.5	58.8	73.2	26.8	100.-
	Dead subst.	31	224	255	2.1	21.3	10.2	29.0	64.7	56.3
	Psammocora	40		40	2.8		1.6	37.4		8.8
OMNIVORES/CARNIV.	P.cactus	36	51	87	2.5	4.8	3.5	33.6	14.7	19.2
	Montipora		40	40		3.8	1.6		11.5	8.8
	Porites		31	31		2.9	1.2		9.0	6.8
	TOTAL	107	346	453	7.4	32.8	18.1	23.6	76.4	100.-
	Dead subst.	50		50	3.4		2.0	100.-		100.-
	Psammocora									
GENER. OMNIVORES	P.cactus									
	Montipora									
	Porites									
	TOTAL	50		50	3.4		2.0	100.-		100.-
PREDACIOUS/CARNIV.	Dir. capt.	37	51	88	2.8	4.8	3.5			
	TOTAL	37	51	88	2.8	4.8	3.5	42.0	58.8	100.-
	Dead subst.	540	568	1108	37.2	53.9	44.2			
	Psammocora	488		488	33.6		19.5			
TOTAL FAUNA	P.cactus	387	150	537	26.6	14.2	21.4	(see Fig. 9)		
	Montipora		210	210		19.9	8.4			
	Porites		74	74		7.0	2.9			
	Dir. capt.	37	51	88	2.5	4.8	3.5			
	SUM. TOT.	1452	1053	2505	58.0	42.0	100.-			

The omnivore/carnivore species are weakly represented in the fringing reef. They seem to chose preferentially the living substrates (37% of total individuals of this group in the fringing reef for Psammocora, 33% for Pavona cactus, and 29% for dead substrate), but they account for a low proportion in comparison with the total individuals collected on each substrate (Tab. 2, Fig. 10).

The generalized omnivore species were exclusively collected in dead substrate at beach margins. They were weakly represented (Tab. 2, Fig. 10).

Among the predacious/carnivore species, Gonodactylus viridis and G.espinosus were only collected in Pavona cactus. Thalamita admete, T.crenata and Calappa hepatica were collected by hand. This group was weakly represented in the fringing reef.

D.2) The Barrier-reef.

The omnivore/herbivore species are numerically dominant on all the substrates of this sector, except in dead substrate, although it is preferentially colonized by them (54% of total individuals of this group in the barrier-reef). For living coral colonies, Montipora is prefered (27%), instead of Pavona cactus (14%) and Porites (5%).

The abundant species are also particularly distributed in the different substrates : in this case, Chlorodiella barbata and C.laevissima are abundant on dead substrate and Montipora, while Pilodius pugil colonize preferentially Pavona cactus.

Montipora is an encrusting coral. The colonies offer free surfaces for algal colonisation (specially in the outer barrier-reef ; Payri, 1982), to which the omnivore/herbivore species are then attracted, but apparently not for the coral species itself.

The relative abundance of omnivores/carnivores is more important in this sector than in the fringing reef. These species become slightly dominant in the dead substrates to which they show strong preferences (65% of total individuals of this group for the barrier-reef). Among living coral colonies, Pavona cactus was better colonized (15%), then Montipora (12%), and finally Porites (9%). Liocarpilodes integerrimus is the dominant specie within this group in the inner barrier-reef, being gradually replaced towards the reef front by other omnivores/carnivores (Globopilumnus globosus, Paraxanthias notatus, Daira perlata, etc.). This scheme could suggest

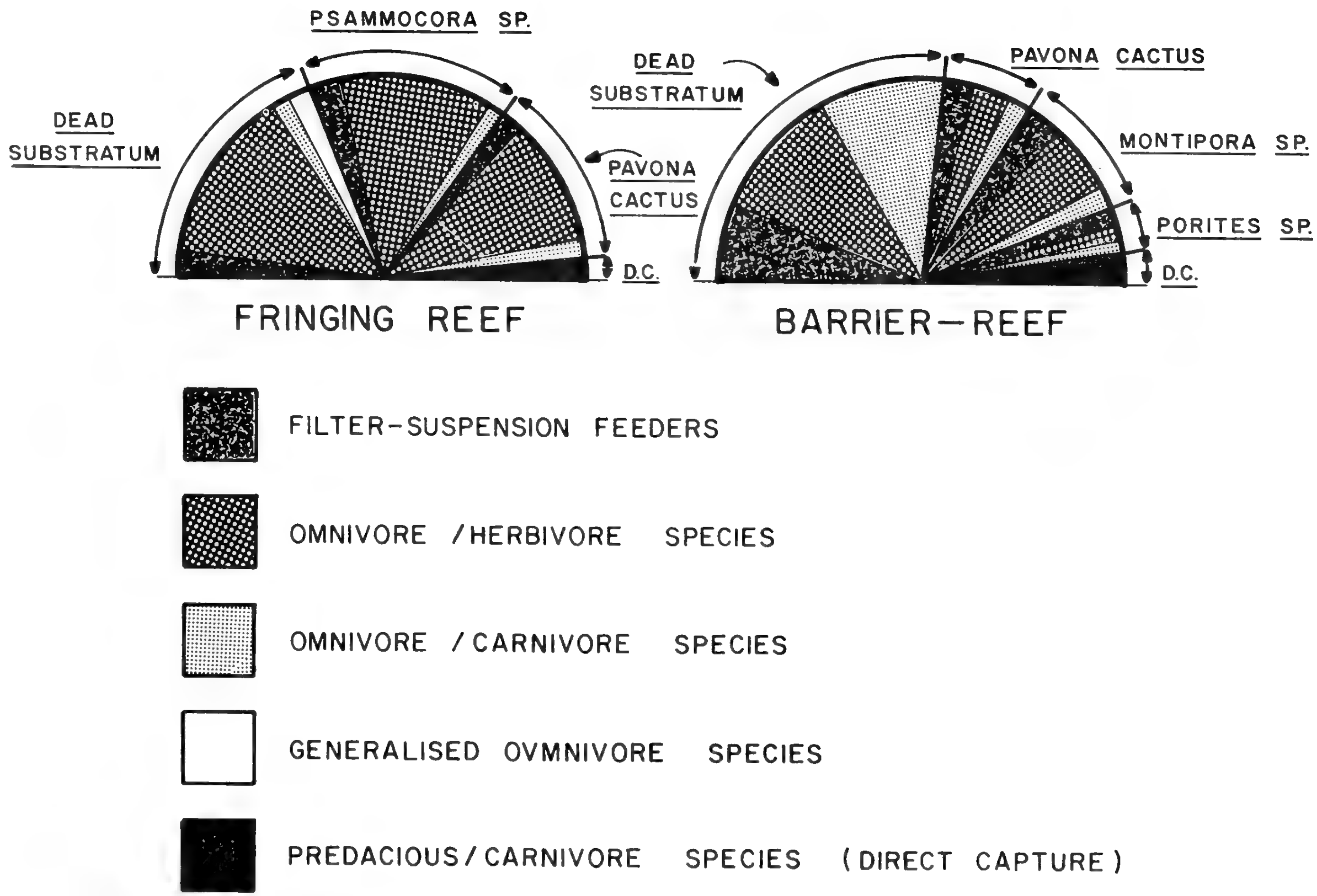

Fig. 10.- Relative abundance of Morphologic Groups in different substrates sampled in each reef sector of the transect of Tiahura (see Tab. 2 for reference).

habitat partitioning among these species which show similarities in their feeding behaviour.

In filter/suspension feeders, *Galathea aculeata* shows also a strong tendency to colonize dead substrates (51% of total individuals of this group for the barrier-reef). Among living coral colonies, *G.aculeata* colonizes mainly *Montipora* (25%), then *Pavona cactus* (16%), and finallly *Porites* (8%).

The predacious/carnivores species are weakly represented in this sector, and most of them are not cavitary. We noted once again *Gonodactylus viridis* and *G.espinosus* only in *Pavona cactus*.

DISCUSSION.

The transect of Tiahura is a reef complex where the most common biotopes of Polynesian High Islands are present (Salvat, et al., 1972). Being a highly diversified environment, the number and the type of species inhabiting it is large and varied. The coexistence of a great number of species within a given area produces interspecific relations often very complex and specialized. Each of the biotopes studied in this work shows an assemblage of floristic and faunistic species, generally well-defined, whose composition depends on the interaction of several factors : presence and distribution of substrates available to colonisation (Connell, 1972 ; Gore, et al., 1978), interspecific relations (Paine, 1974), complexity of biotopes (Kohn & Nybakken, 1975), biotic and abiotic environmental conditions (Abele, 1972 ; Connell, 1975), and bioecologiccharacteristics of the species concerned.

The 73 species collected at Tiahura are adjusted to this schema, and although the dominant species tend to a wide distribution in the transect, the qualitative compositon (and mainly the quantitaive composition) of populations is rather different from one area to another. These differences are defined, first, by the spatial distribution of the 10-12 species following in abundance the 4 dominant species, and second, by the particular repartition of each species in the substrates.

In agreement with Abele (1972), Gore et al. (1978), and others, the numerically dominant species within a biotope are generally those that possess the best adaptations (morphological or others) for favorable exploitation of their resources. One of these adaptations which seems to have a strong influence over the community composition in the different biotopes is the alimentary regime of species (Odum & Odum, 1955 ; Paine, 1966).

The type of food of crustaceans is closely related with the morphology and the size of the species, both the consumer and the prey (after different authors). On that basis, we have proposed 5 MORPHOLOGIC GROUPS. In each are included species having morphologic similarities which may indicate the utilisation of the same kind of food. These divisions are not strict : crabs are well-known to show tendences to omnivorism, and the high diversity of a high island coral reef system may favor a non-specialized feeding behaviour, the choice of resources being quite large.

Nevertheless, some morphologic features observed in the crustaceans in our work suggest that there actually exists a certain degree of feeding selectivity. Besides, the similar sizes of species (most of them do not measure more than 20 mm width in their adult stage), suggest the utilization of similar alimentary resources, and in consequence, there would be a competition for these, for they are certainly not unlimited. This condition confirms the existence of alimentary specialisation, mainly in abundant species, as mentioned by Gore, et al. (1978).

The effect of this specialisation is reflected in the repartition of species in the transect and in the different substrates. Two factors inherent to the substrates studied could determine these differences : the degree of necrobiosis of the coral colony which permits a more or less extensive colonisation by algae and their associated fauna, and the complexity of the cavitary network which offers adequate shelter to the cryptofauna. In these terms, the dead substrate would be the best, it shows a high algal colonisation, an abundant associated fauna, and in most cases, a well-developed cavitary network. For living corals, _Pavona cactus_ and _Psammocora_ present more favorable factors for the colonisation by the carcinologic cryptofauna, which is not the case for _Porites_ (the colony is compact with few or no anfractuosities).

Moreover, it is necessary to take into account the effect of the ecologic conditions proper to each reef sector. Thus, the transect of Tiahura is spatially shared by the omnivore/herbivore species that prefer the fringing reef where dead substrate (and therefore algae), is more abundant, and by the omnivore/carnivore species that tend to aggregate in the barrier-reef, mainly in the outer reef flat and the reef front areas, where polychaetes and molluscs, their principal food respurce, are more abundant (Peyrot-Clausade, 1976 ; Naim, 1980b ; Richard, 1982). The filter/suspension feeders search for low-sedimentation areas with moderately strong currents (inner barrier-reef), favorable to their filtering activi-

ties, while the generalized omnivores prefer the areas of organic deposition (shallow beach margins). Predacious/ carnivores species are not abundant in lagoon areas of the transect, although some facultative malacophages are localized in the reef front.

Within each of the morphologic groups, there are one or two numerically dominant species whose repartition over the transect of Tiahura, and in the different substrates suggests the influence of a trophic partitioning phenomenon (Schoener, 1974 ; Gore, et al., 1978). The four most abundant species in the transect (Chlorodiella barbata, Pilodius pugil, Liocarpilodes integerrimus and Galathea aculeata), utilize apparently different types of food, are distributed in a particular pattern in the substrates, and occupy more or less the same areas. The five or six following species also seem to show these three types of relationships. There would exist therefore, two main strategies to avoid or to reduce competition among these species : a trophic partitioning by restriction of their alimentary regime when two or more abundant species live in the same area (in this case each species will show different alimentary needs), and a habitat partitioning when two species living in the same area search for similar alimentary resources (here, one of the species would be less restrictive than the other in its alimentary regime, thus able to exploit a more extensive biotope, i.e. inhabit other types of substrate), or, if competition is inavoidable, a spatial exclusion takes place.

Interspecific relations are quite clear, in the present work, among the dominant species and among some of the abundant species, both in terms of spatial distribution and repartition on the substrates. However, the picture becomes more complex when more species interact. In this case, it is possible that interspecific relations would occur with assemblages of species. We may mention Liocarpilodes integerrimus (omnivore/carnivore : dominant species), with the group of less abundant omnivore/carnivore species in the barrier-reef and the reef front (Globopilumnus globosus, Paraxanthias notatus, Daira perlata, etc.) ; Chlorodiella barbata and Pilodius pugil (omnivores/herbivores : dominant species), with the group of omnivore/herbivore species in the fringing reef (Phymodius ungulatus, P.nitidus, Pilodius scabriculus, etc.)

Abele (1974) and Gore, et al. (1978), stated that marine decapod crustaceans utilize the substrate in three main ways : 1) as a permanent shelter, 2) as a feeding site, 3) as a direct food resource.

The data obtained in this study agree with these findings, more than 90% of the species collected utilize the cavitary substrate as shelter (except endogenous and "free living" species). Then, the observations of gut contents suggest that species utilize the substrate also as a feeding site. But concerning the utilisation of substrate as a direct alimentary resource, this could only happen in living corals, and it is not always evident. Except for some of the well-known coralivores pagurid crabs, we cannot demonstrate the existence of other coralivore species (either strict or facultative), although this posssibility is likely to occur, chelipeds with sharp-pointed fingertips would be morphologically adapted to crush the outer surface or the coralites and then extract the soft tissues from the interior. Gore, et al. (1978), observed a similar behaviour in *Menippe nodifrons* inhabiting the sabellariid reefs.

Predation activities among crustacean species appear limited. Certain more or less large-sized species such as *Globopilumnus globosus*, *Xanthias lamarcki* and *Daira perlata*, may probably attack smaller species inhabiting the same area (*Lioxanthodes alcocki*, *Paraxanthias notatus*, *Liocarpilodes integerrimus*, *Chlorodiella laevissima*, etc.). Juveniles, and individuals undergoing molting stages could also become prey. Besides, malacophage crabs would consume numbers of pagurid crabs inhabiting gastropod shells (Rossi & Parisi, 1973).

Finally, we may define the transect of Tiahura as a topographically complex and irregular habitat, having a relatively constant abiotic environment, which favors a high specific diversity and numeric abundance. However, it is not favorable to an ecologic specialisation of species and to the presence of large predacious crabs.

The statement by Kohn (1968, 1971a) for *Conus* populations, and by Abele (1974) : "more structurally complex habitats could support a higher number of species than structurally simpler habitats", would have been confirmed if we had compared the crustacean communities of High Islands and atolls, a study that should be done in the future.

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CHINCHORRO:

MORPHOLOGY AND COMPOSITION OF A CARIBBEAN ATOLL

BY

ERIC JORDAN AND EDUARDO MARTIN

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SUMMARY

Chinchorro, one of the largest Caribbean atoll s, is located eastward of the Yucatan Peninsula and north of the Belize reef-complex. The morphology of this atoll and it's reef structures on the windward and leeward margins are described down to a depth of -60m, as well as the reefal formations of the enclosed areas. An account of the species composition of scleractinians and gorgonians in all reef zones is carried out, together with brief references to other open substrate controlling organisms such as algae and sponges.

Chinchorro atoll is characterized by gradual and clear morphological changes north to south, along its longest axis, both in the enclosed and exposed areas. The general morphology of the reef structures on the windward margin of the atoll, are greatly influenced by the depth of the subjacent substrate and the presence of an extensive and gently dipping platform; this platform is not found on other western Caribbean atolls.

Most interesting are the complex spur and groove systems that show a gradual change from multiple systems of spurs, to a series of complex but poorly developed ridge systems and then to local disappearances of these features at several sections of the atoll. The lagoon areas also reflect a change in the reef formations due to a depth gradient along the south to north, major axis of the atoll.

INTRODUCTION

Chinchorro Atoll, off the south-east coast of the Yucatan Peninsula, is one of the largest structures of its type in the Caribbean basin. Due to its size and geographical position, north of the Belize reef complex, Chinchorro Atoll has aroused a strong interest in the scientific community. However, few studies had been completed on the atoll, notwithstanding that the Belize reef complex has been intensively studied in the past two decades (Stoddart, 1962; Purdy, 1974; James and Ginsburg, 1979; Rutzler and Macintyre, 1982a).

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Chinchorro Atoll was well known to the Spanish sailors of the sixteenth century and was probably named Triangulo, by them. English seaman also had an interest in it, and it was charted in 1839 by Barnett, although the chart was not published until 1850 (Stoddart, 1962); this chart however, is still the best one available. Darwin (1842) mentioned a reef named Northern Triangles, probably Chinchorro Atoll, between Turneffe Islands and Cozumel Island, while discussing the nature of the Western Caribbean reefs. Incidentally, none of the Belizean atolls, nor Chinchorro Atoll, were considered by him to be true atolls formed by subsidence (Darwin, 1842). Griscom (1962) visited the cays of Chinchorro Atoll in an ornithological expedition and made some comments on the reefs. Stoddart (1962) reviews the information available on Chinchorro Atoll at the time. And Chavez (1984) decribed the general characteristics of the atoll and bottom biota. However, very little is known of the reef structures that constitute this atoll.

The purpose of this paper is therefore, to give the first detailed and systematic description of Chinchorro Atoll morphology, of its reef structures, and of the species composition of substrate-controlling organisms.

GENERAL SETTING OF THE STUDY AREA

Chinchorro Atoll (18° 35′ N and 87° 25′ W), is located 30 Km eastward from the Yucatan Peninsula and about 100 Km north from Turneffe Islands and Lighthouse reef in Belize. It is 47 Km long, 18 Km wide and has a total area of more than 700 square Km (Fig. 1).

The atoll foundation rises from a submarine ridge shaped by normal faulting, upon which the Turneffe Islands are located (Dillon and Vedder, 1973). This ridge was constructed during the formation of the Yucatan basin and later modified by considerable coral reef accretion (Enos et. al., 1979). Dillon and Vedder (1973) suggest that the basements of Turneffe Islands and Glovers Reef (1000m and 570m of coral limestone respectively), were deposited during slow subsidence of fault blocks, at the same time that the Cayman Trough was developing in late Cretaceous and early Tertiary times.

CLIMATE AND HYDROLOGY.- The southern part of the Yucatan Peninsula has a subtropical climate, AW (x), Koeppen modified system (Garcia,1964). The rainy season lasts from June to October; after this period, sporadic heavy rainfall could occur during winter and early spring due to the cold north winds. The annual average rainfall on the mainland is around 1400 mm. Trade winds are the dominant ones through the year, although north winds may predominate from October to May. Hurricanes are the major climatic event of the year, from June to November. According to Gentry (1971) there is a 50% per year probability that a hurricane will strike the Yucatan Caribbean shoreline.

There is little information on hydrology and water movement around the Chinchorro Atoll area. Most of the available information comes from references to sporadic measurements in the Belizean reef formations

(Stoddart, 1974; James and Ginsburg, 1979; Burke, 1982; Greer and Kjerve, 1982 and Kjerve et al., 1982). Merino (in press) followed the oceanic current patterns with drift cards, on the leeward and seaward of the atoll. Wust (1964) considers that somewhere between the Belizean atolls and Chinchorro, the surface current is deflected by the continental mass towards the Yucatan Channel. The presence of strong, but sporadic countercurrents over the fore reef on the windward and leeward side of the the atoll, has been repeatedly observed by the authors.

METHODS

The study of the atoll was carried out through two types of activities, during three cruises to the atoll in 1979, 1983 and 1984. In the first instance, several west to east and north to south transects were made, in order to obtain a general knowledge of the atoll characteristics. Data obtained during these transects refer to bathymetric profiles, general morphology of the area, identification of the reef structures, substrate type and condition, and biotic associations present. Secondly, based on the information obtained from the transects survey, selected sites of the windward and leeward margins, and in the lagoon area of the atoll, were chosen for detailed analyses of the reef morphology and biota present.

In the selected sites (chosen because prominent morphological features or grounded ships), the nearby area was surveyed both by towing and swimming divers, in order to verify the commonness of the features to be analyzed. Observations on the selected sites consisted of measurements of depths, dimensions and distribution patterns of the reef structures, as well as registers of bottom types, and species composition of substrate controlling biota.

Depths were determined with small portable echosounders or with diving depth gauges, depending on the extent and depth of the study area. Reef dimensions were measured with marked lines. Species abundance and coral cover by direct observation in 5, 25, 50, 75 and 100% categories; spatial reference while estimating the abundances was given by the measuring lines. Identification of the coral species was done "in situ" whenever possible, following Wells (1956), and Goreau and Wells (1967); Gorgonians after Bayer (1961); Sponges after De Labeunfels (1955) with help from P. Gomez (UNAM), and macroalgae after Taylor (1972) by Dr. Laura Huerta (IPN). The grounded modern ships that border the eastward margin of the atoll and rise more than 10m above sea level, were used as permanent stations whenever possible, and together with the cays, as positioning points all along the study area. Grounded ships location on the atoll were fixed by radar and sextant bearings (Fig. 1).

MORPHOLOGY AND CONSTITUTION OF CHINCHORRO ATOLL.

The peripheral reef on Chinchorro Atoll measures about 115 km (Fig. 1). The longest axis of the reef (south to north) is parallel to the East margin of the Yucatan Penisula. Three cays are found inside the atoll, Cayo Norte (0.9 square km), Cayo Centro (6.1 square km) and Cayo Lobos (less than 0.1 square km). Cayo Norte and Cayo Centro are covered with mangroves and scattered coconut palms. Cayo Lobos, the only cay close to the windward margin of the atoll, has no palms nor mangroves and is covered mostly by bushes. Coral rubble constitutes the beaches.

The rim of the atoll is shallower on the windward margin (-0.1 to -0.4m), than on the lee of the atoll (-1 to -2m). Only two channels exist on the seaward rim, both in the middle section. The largest one named "Quebrado" is up to 150m wide and 8m in depth; large coral heads inside this channel make navigation difficult for large vessels. The small channel is "Boca Chica", only about 2m deep, and difficult to locate from the sea (Fig. 1). On the northern section of the windward margin of the atoll, the reef crest is interrupted at many places.

The lagoon is shallow, ranging from -10m in the southern section to -1 or -2m on the northern one. The south section is characterized by the presence of numerous patch reefs and coral knolls. Some of the patches are quite long (up to 3 km) and parallel to the windward margin. The number and size of the patch reefs decrease gradually from south to north, although they are always present on the lagoon. In the north section they are located mainly on the central area.

Chinchorro Atoll is not uniform, there are clear differences in the morphological features and reef formations, both from windward to leeward and from south to north. In order to facilitate its description, we have arbitrarily divided the reef into a windward, a leeward, and lagoon sections; in each one of these, the description will be started from the south and will proceed toward the northern end of the atoll.

WINDWARD SECTION

The windward margin of the atoll is characterized by the presence of an extensive and gently dipping platform, descending at a low angle (from 3 to 8 degrees) down to -35 to -40m, where it gives way to an almost vertical slope beyond -60m (Fig. 2). This flat, calcareous platform, which is the most important morphological feature on this margin, seems to strongly determine the reef characteristics, as is discussed below.

The windward margin includes all the area that corresponds to the rear reef zone, the reef crest zone and the fore reef zone. The description will proceed accordingly and, as stated before, from south to north when differences are recognized.

Rear Reef Zone

In the southern and central sections of the atoll the coral growth on the rear reef zone extends for 80 to 150m, between the reef crest and an extensive sandy area that constitutes part of the rear reef platform.

Close to the reef crest, in depths of 1.0 to 1.4m elongated calcareous structures like small ridges, are found. These ridges have a perpendicular layout to the reef crest, and are not related with the grooves and depressions of the crest. These structures are from 0.5 to 1.0m high, from 6 to 10m long and 2-3m wide. In the spaces between adjacent ridges, coral rubble is abundant upon a calcareous substrate covered with a fine layer of sand. Toward the reef crest, the dominant species is *Millepora complanata*, which is gradually replaced by *Acropora palmata* and *Agaricia tenuifolia*, as distance from the crest is increased. This spatial succession was clearly observed in all the ridges. Colonies of *Montastrea annularis*, *Acropora cervicornis* and *Acropora prolifera* are common upon the ridges (Tables 1 and 2).

The bottom of the rear reef, close to the reef crest, is covered by rubble, which is gradually replaced by a thick layer of sand. Upon the rubble the only scleractinian present is *Porites astreoides*, and dense algal mats of *Turbinaria turbinata*, *Stypopodium zonale* and *Caulerpa racemosa*. No crustose calcareous algae were observed in these algal mats.

Lagoonward, the rubble gradually disappears, giving place to a sand platform which may extend for another 200m (shorter in the Central section). This sand platform ends abruptly into the lagoon bottom in the form of a sand wall 2 or 3m high. The sand platform is primarily inhabited by sparse clusters of macroalgae of the genera *Penicillus*, *Halimeda*, *Udotea* and *Ripocephallus*. No seagrasses were observed. Few, relatively large coral patches are found on this platform. A depression in the sand bottom usually surrounds the patch, -0.8 to -0.9m below the sand platform level. These patch reefs are from 3 to 8m in diameter and up to 2.5m in height, highly eroded, forming caves that provide shelter for reef fishes. The dominant coral on these patches is *Montastrea annularis* and the composition of the remaining coral fauna is similar to the one found on the rear reef zone ridges (Tables 1 and 2).

In the north section, the rear reef zone is different from the south and central sections. It consists of a calcareous pavement which extends toward the lagoon whithout conspicuous reef structures. The bottom is covered with coral rubble, sand, and small and scattered scleractinian colonies where *Porites astreoides* dominates; but in general it is poorly populated by corals. Water depths range from -2.4m at the deepest parts to less than -1.0m beside the reef crest. The inner limit of the rear reef in this section is difficult to estimate, since there is not a clear edge separating it from the lagoon zone. In fact, in the NE corner of the atoll there are no apparent changes in the bottom characteristics until Cayo Norte is reached, although there

is an increase in the number and size of the sand patches towards the cay.

Palythoa caribbea is relatively common and many patches cover small areas of substrate on the rear reef zone. Millepora complanata may form thin crusts of no more than 15cm high, including the upward growing blades. In most places however, the substrate is exposed or covered by filamentous algae, growing directly upon the calcareous pavement. Dense mats of the brown algae Turbinaria turbinata are found during the summer months. Gorgonians are also scarce (Table 2).

Reef Crest Zone

The crest zone has well developed and defined reef structures on the south and central sections of the windward margin of the atoll. On the north section however, there are few reef structures and the zone is basically denuded.

In the southern and central sections, the crest zone constitutes a calcareous crust that extends from the rear reef zone to the beginning of the spur and groove system, and constitutes the rim of the reef. The upper part of the crest zone is very close to the water surface (from -0.2 to -0.3m) and relatively deep and narrow channels (-1.0 to -1.3m deep, 1.0 to 1.5m wide), run through the crest connecting the rear reef with the fore reef (Fig. 3). In the area of the ship "Tobacco Trader" (Fig. 1), the channels do not cut through the fore reef, instead they end in small pools inside the crest.

Few coral colonies were found on the crest, which is mostly covered by nodulous and branched calcareous algae of the genera Neogoniolithon, Lithothamnium, Ephilithon and others. Although these algae do not form a separate structure, they resemble the algal ridges at Holandes Cays in Panama (Glynn, 1973), and the coralline microatolls in Cozumel Island (Boyd et al, 1963). These algae mostly grow close to the surface where they form an irregular lip, broken at many places.

On the north section the crest zone is not as well defined as in the previous sections. Here a flat, calcareous pavement, forms the crest. Coral colonies are seldom found upon this pavement. The crest is relatively deep (-0.6 to 1.0m) and constitutes a continuation of the also relativeley flat calcareous platform that constitutes the beginning of the fore reef. Toward the lagoon, as explained above, the calcareous bottom prevails, with few abrupt changes in the bottom regularity. Fleshy and filamentous algae, and large colonies of the sponge Anthosigmella varians are the main biotic components in the area.

Fore Reef Zone

In the shallow areas of the fore reef zone, a complex system of spur and grooves is found. The complexity of this system is one of the most interesting features of Chinchorro Atoll (Fig. 4) and is discussed in

detail elsewhere (Jordan and Martin, in preparation).

The presence of the spur and grooves is utilized in this paper to divide the fore reef zone in two subzones: 1) the inner fore reef (IFR) where well developed and growing spurs are found, down to a depth of -15m, and 2) The outer fore reef (OFR) seaward from the IFR all the way to the edge of the fore reef zone where the insular slope begins (-60m approximately). On the OFR actively growing spurs are not found, but calcareous ridge-like structures, with a parallel layout similar to the spur and groove system are found in many localities and at different depths.

1) <u>Inner Fore Reef</u> (IFR).

The spur and groove system varies in complexity along the windward margin. This system is better described by isolating its constitutent elements. In this paper the whole spur and groove features of the IFR at the windward margin are considered as a system: the spur and groove system (SGS). The system includes several sets of spurs, whose dimensions and spatial patterns vary from one locality to another.

On the south and central sections, the first sets of the SGS consists of buttress-like spurs, and together with the reef crest form a calcareous rim that extends from the rear reef zone to the seaward limit of the buttresses. These spurs are very wide and irregular adjacent to the crest. As the spurs extend seaward, they become thinner and more regular (Fig. 5). The spurs are deeply eroded and pitted and almost devoid of corals at the shallowest end, but are covered by crustose algae. The sides of the spurs and the seaward face are also irregular and abruptly sloped. As water depth increases, a prolific coral assemblage, in which <u>Millepora complanata</u> and <u>Porites astreoides</u> are the dominant species, gradually substitute the algal cover. The bottom of the grooves is filled with coral rubble and almost no sand at all (Tables 1 and 2).

Seaward from the first sets of spurs, a second set appear. In the south section at the area of the ship "Falstaff", the spurs of the second set, which are longer than 100m, interfinger with the spurs of the first set (Fig. 4). Northward, at the Cassel's area in the Central section of the atoll's margin, there is no intermingling between the spurs of the first and second sets (Fig. 6). A flat platform extends for 30 to 40m between both sets, clearly setting them apart from each other (Fig. 4). The second set of spurs are the most developed ones of the SGS in all localities. Living coral coverage on these spurs approaches 100%. <u>Millepora complanata</u>, <u>Agaricia tenuifolia</u> and <u>Porites porites</u>, together with large colonies of <u>Acropora palmata</u>, are the dominant species (Tables 1 and 2).

At the area of the "Cassel" ship, a clearly distinct third set of spurs, separated by no more than 2 or 3m of distance from the second one, is found. Living coral cover upon these spurs is notably lower

than that found on the previous sets, although some large colonies of _Acropora palmata_ and _Montastrea annularis_ are present.

Approximately four miles northward from the Cassell area, but still on the central section of the atoll, at CW-1, the second set of the SGS has spurs that are much wider than those on southern locations. The distance between spurs (on the order of 20 to 40m) is also greater. The large spurs of this locality are also asymmetrical, an asymmetry that seems to arise from a differential coral growth between the north and south slopes of the spurs (Fig. 4).

At the north section of the atoll, no SGS or any other reef structures are found in the IFR area, where the fore reef is a flat, calcareous pavement similar to the one that constitutes the reef crest (Fig. 4). _Millepora complanata_ is abundant from -2.0m to -3.0m, disappearing at depths greater than -3.5m, where the IFR becomes a barren area, similar to the one found on the NE continental reefs of the Yucatan Peninsula (Jordan et al., 1981). On the barren area, depressions and holes pit the calcareous pavement, and a diverse but scarce coral fauna thrive (Tables 1 and 2).

2) _Outer Fore Reef_ (OFR).

The outer fore reef is basically determined by the flat, calcareous pavement that constitutes the fore reef platform. However, upon this platform several reef features are found, features that as in the SGS, vary from one locality to another. These reef structures are not referred to as spurs in this paper, in order to differentiate them from the actively growing ones found at the SGS. Instead, and because of their low height and scarcity of coral cover, we will refer to them as ridges.

On the southern section, at the Falstaff ship site, beyond the SGS, at a depth from -25 to -35m, the fore reef is sparsely covered by aggregations of sponges, algae, gorgonians and corals, constituting small rounded patches a few meters in diameter and no more than 1.0 to 1.2m in height.

On the Central section at the Cassell ship area, and seaward from the third set of the SGS, at a depth of -18m, long ridges with very gentle slopes and a height of only 1.0 to 1.5m, resembling elongated hills, are found. These ridges have a consolidated calcareous structure and living coral cover is rather low, while gorgonians and sponges are abundant (Tables 1 and 2). The ridges have a parallel layout, perpendicular to the reef crest (Fig. 4).

Several sets of these ridges occur in progresive stages as the bottom becomes deeper, and although the ridges do not appear to be continuous from one set to another, some sets are so close to each other that their ridges overlap). At a depth of -40 to -45m, before reaching the edge of the fore reef platform, the ridge system disappears, giving place to small rounded patches similar to the ones found on the South

section.

At the CW-1 area, a very similar layout was found, with the ridge sets starting at a depth of -18m (Fig. 4). The coral biota is similar to that from the bottom platform, in which gorgonians predominate and the scleractinians are represented mostly by small colonies. Sponges are also extremely abundant (Tables 1 and 2).

On the north section at the NW-1 site, where there is no SGS, from a depth of -18m down to -25m, similar ridges to the ones previously described are found. The layout is not as regular as on the other sets at the southern areas. Living coral coverage is rather low, gorgonians and sponges are extremly abundant (Tables 1 and 2).

At NW-2, in the northern end of the atoll, the outer reef is different. From the crest area to a depth of -15m a sand covered slope is found, and at -20m a set of rampart or small wall-like ridges appear. These ridges are similar to the ones described above, but somewhat larger and with a very uniform layout (Fig. 4). This ridge set ends abruptly at -27 to -30m, where a marked increase in the slope of the bottom occurs (to more than 35°), continuing down to -50m, where the slope ends in a horizontal sand-covered platform. On this deeper slope, another set of wider and higher ridges are found. The coral biota upon the ridges is again similar to the one found on the other ridge systems, although the scleractinian cover is higher.

Lagoon Zone

As it happens in the windward margin, the lagoon reef structures change along the longest axis of the atoll, basically as a function of a northward decreasing bottom depth (Fig. 8).

In the South section, where the average depth is -7m to -9m, numerous patch reefs are found. Lagoonal patch reefs vary in size and shape, as well as in the scleractinian dominant species, depending on the locale and orientation of a given patch. We divided the patch reefs found inside the lagoon, into three main types: 1) well developed, 2) low lying patch reefs, and 3) elongated patch reefs.

Well developed patches, reach the water surface even in the deepest parts of the lagoon (Fig. 9). In these reefs, large colonies of _Montastrea annularis_ form the edges and dense and extensive sheets of _Porites porites_, surround these formations as a secondary belt. In the innermost lagoonal patches, the upper portion of the patch is covered by algae of the genera _Penicillus_ and _Udotea_ and sometimes by extensive beds of _P. porites_. In the southernmost patch reefs, which are exposed to the refracted waves entering through the open atoll margin between Cayo Lobos and Wreck Reef, _Acropora palmata_ is the dominant species, surrounded by extended thickets of _Acropora cervicornis_ and isolated heads of _M. annularis_. The lagoon bottom between patches, consists of a hard bottom covered by sand, mostly

devoid of seagrasses or algae. Coarse coral rubble predominates on the nearby area of Cayo Lobos.

Low-lying patch reefs are composed mainly by extensive and dense masses of mostly dead A. cervicornis and big colonies of M. annularis, that can have a relief of more than 2m over sandy bottoms of -6 to -8m in depth. These colonies show a significant bioerosion and are covered on the top by algae. Colonies of Colpophyllia natans, Solenastrea buornoni and Siderastrea siderea are also present, mainly in areas adjacent to these formations. Gorgonians are not very abundant on these shoals, and colonies are in general small or medium-sized (Fig. 9).

The elongated patch reefs are found on the area of LP-1 and LP-2 sampling stations (see Fig. 1) These barrier -like reef structures rise only 2 to 3m from the bottom without reaching the surface, and tend to run parallel to the atoll's rim. The largest one, exceeds 3Km in length and is 50 to 100m wide, rising from a -7 or -8m lagoon bottom (Fig. 9). The S and SW sides of these patches, have a steep slope ending on the sand covered bottom, where dense aggregations of the queen conch Strombus gigas are seen close to the shoal. By contrast, the east side has a smooth slope towards the adjacent sand floor which is noticeably covered by macroalgae. Massive multilobated colonies of Montastrea annularis grow in both edges, but those on the seaward side are bigger. As in the well developed patch reefs of this area Acropora palmata is mostly absent, and if present it is very scarce. Gorgonians are rare on the windward slope of these elongated patch reefs (Table 2).

On the central section average bottom depth is -4 to -5m, although in some places it could be as much as -7m deep (Fig. 8). The biggest cay found in the atoll, Cayo Centro is located in this section. The cay is surrounded by a shallow lagoon covered by the seagrass Thallassia testudinum. The dense beds of this phanerogam gradually diminish away from the cay, giving place to sandy bottoms dominated by calcareous macroalgae. Scattered gorgonian colonies are found on this environment. On the leeward side of the lagoon an extense calcareous platform covers most of the bottom. This platform of only 2m in depth is barely covered by biota or sand, and no significant reef features were found upon it.

Patch reefs in the central section are less abundant than in the south section and tend to be located in the deeper middle lagoonal area and, to a lesser extent, in the seaward side. Two different types of patches characterize this section of the lagoon. Some are quite small, with diameters of about 20 to 30m, always circular in shape and rising 3 to 4m above the bottom without reaching the surface; the main coral builder of these patch reefs is Montastrea annularis. The other patch reefs are also non-emergent but are irregular in shape, with a tendency to have their longest axis parallel to the longest axis of the Atoll (Fig. 9). Both types are characterized by a poor development of corals (Table 1). Gorgonians, on the other hand, are very abundant and diverse (Table 2). The substrate is extensively covered by macroalgae. Where patch reefs are found in the Thallassia testudinum area, a ring free of seagrass surrounds the patch, presumably maintained by grazing act-

ivity (Ogden et al., 1973).

The north section of the lagoon is even shallower than the central one. Average depth is -1 to -2m, but could reach as much as -5m towards the center (Fig. 8). A scarcity of patch reefs characterize this part of the lagoon, where two cays (Cayo Norte) are present in the northern tip of the atoll. The sandy bottom of the lagoon floor around them, is covered by dense beds of Thallassia testudinum which are gradually replaced by dense algal patches, away from the cays. These patches are composed mainly by species of the genera Laurencia, Lobophora, Dictyota, Halimeda, Udotea and ocassionally Penicillus, which cover extensive areas of the lagoon bottom. Scattered big, massive sponges of the genus Ircinia and some isolated colonies of the gorgonian Pterogorgia anceps are also present growing upon the sandy bottom.

From the cays towards the windward rim, the lagoon bottom gradually changes from sand patches to a calcareous hard bottom, making it difficult to determine where the lagoon ends and the rear reef begins. On the lee of Cayo Norte a sandy area extends for a few hundred meters. Gradually, this sand cover disappears exposing the calcareous bottom that predominates in the western area of the lagoon, both on the central and north sections of Chinchorro Atoll (Fig. 8).

LEEWARD MARGIN

In the leeward margin of Chinchorro Atoll there is not a well defined reef crest and reefal structures are less prominent than the ones on the windward margin of the atoll.

In the south section of the atoll from Cayo Lobos, westward to Wreck Reef, the external contour of Chinchorro Atoll is marked by a series of rim-banks that resemble a chain of little coral islands, recognized only by the breaking waves and changes in bottom appearance (Fig. 1). These banks have an elongated shape, with the longer axis parallel to the edge of the atoll and range in length from a little more than 100m, to less than 800m, with an average size of roughly 400m. The width of the channels between the banks also varies, from 300 to almost 2000m. The depth of these channels ranges from -5 to -11m. The depth at which the upper surface of the rim-banks is found, decreases gradually from -4 to -5m at Skylark Ledges, to less than -2m at Wreck Reef.

The rim-banks on the Skylark Ledges area are formed by patches of scleractinian corals interspersed with sandy areas, where no zonation pattern is apparent. These banks normally rise only a couple of meters above the bottom and the coral fauna is dominated by dense stands of Acropora palmata and A. cervicornis. Porites porites forms extensive carpets alternating with sand patches, where large isolated coral heads of Montastrea annularis are found. The general appearance of these rim-banks is that of a group of clumped coral heads.

Other rim-banks more on the leeward margin, like Blackford and Wreck Reef, present a clear zonation pattern from seaward to leeward. A section of the bank will give the profile of an asymmetrical dome, with the peak close to the leeward side (Fig. 9). A. palmata covers the peak, with dense stands of large and sturdy colonies, strongly oriented toward the fore reef. Between the A. palmata stands, extensive patches of A. cervicornis are found. These are surrounded by elongated thickets of Agaricia tenuifolia. From the peak of the bank, the bottom gradually descends to -4m, where a small cliff of 2 to 3m marks the end of the bank. This cliff is covered by large colonies of Montastrea annularis, Colpophyllia natans and Meandrina meandrites, whose abundance and magnitude diminish toward the fore reef side of the bank. Gorgonians are abundant and diverse (Tables 1 and 2).

From Wreck Reef to CL-1, the rim-banks gradually disappear and are substituted by a continuous calcareous rim, that extends from the central to the north part of the atoll. Between Wreck Reef and the calcareous rim, two or three rather elongated rim-banks, are still found, where a poor zonation pattern is present. They reach an average length of 600 m, while the channels average about 60 m in width; the depth varies from -2 to -4 m (Fig. 1).

From CL-2, all the way to the northern end of the atoll, a wide and flat calcareous platform delineates the shallow rim (-1 to -1.5m) on the leeward margin. Here, there is not a sharp limit between the reef crest and the rear reef, either from the biological or the morphological point of view. Although in some places along the rim, small coral patches reach the surface forming a local crest; these coral buildups are more abundant in the central and north sections, but do not show an order of appearance (Figs. 1 and 4).

Fore Reef.

The fore reef on the leeward side of the atoll is drastically different from that of the windward side. The extensive fore reef platform of the windward margin is not found here. Spur and groove systems are also absent on the leeward margin, although ridge systems are found both on the south and north ends of the atoll.

On the southern section at Wreck reef a ridge system appears upon a relatively short and bare calcareous platform. This system consists of parallel ridges perpendicular to the longest axis of the atoll, with a spatial distribution that resembles a spur and groove system. The ridges of this system, however, are very thin (from 2 to 3m in width) and do not appear to be actively growing (Fig. 4).

The system consists of three intermixed sets of ridges, in the first set at approximately -8m, the ridges attain a height of almost 4m, decreasing gradually in height along its length (40 to 70m) to less than half a meter at the seaward limit at -10 or -12m. Before the first set of ridges disappear, it overlaps a second set. The ridges of the second set are only 1 to 1.5m in height at the beginning, and also

decrease in height as depth increases, and they are somewhat shorter than the ridges of the first set. Again, before the ridges of the second set reach their end a third set of ridges is found, also overlapping with the ones of the second set. The ridges of the third set rise only 0.5m above the bottom, and they look more like an ordered line of small rocks rather than ridges. The pattern however, is similar to the other ones. The third series ends at approximately -18m.

The ridges consist of consolidated calcareous material which is deeply pitted and eroded, but they support a relatively rich coralline fauna. Coral cover, at the shallowest parts of the ridges of the first set, is greater than 50 or 60%. Scleractinians show a clearly decreasing gradient in colony size and number of colonies, from the shallow to the deeper parts of the ridges, and concordantly, from the first to the third set of ridges. The dominant species found upon the ridges are Montastrea cavernosa, M. annularis, Siderastrea siderea and P. porites (Tables 1 and 2).

Beyond the ridge system and down to the outer limit of the fore reef platform (-33m), abundant coral patches of 2 or 3m in diameter are found; these are abundantly covered by scleractinians, gorgonians and sponges. On the fore reef colonies of Xestospongia muta up to 2m in height are common (Fig. 10). At the outer limit of the fore reef platform, the patches increase both in size and number, forming a deep coralline rim of more than 3m in height, which provides a substrata for many organisms of the coral community. The alga Lobophora variegata can be highly abundant, thus covering a considerable fraction of the substrate. Carbonate sand with a thickness in excess of 0.5m covers the hard substrate, between the coral patches (Fig. 11).

Coral composition is similar for the platform and reef slope area, the main species are Agaricia fragilis, A. agaricites, Montastrea cavernosa and Mycetophylia lamarckiana. Gorgonians are also relatively abundant, their species composition is similar to the platform area (Tables 1 and 2). On the fore reef slope down to a depth of -45 m, coral patches and rocky outcrops with no apparent order and with a conspicuous coral/algal biota living on them, are still very abundant. As depth increases, patch size is gradually reduced and sponges and non-symbiotic gorgonians of the genera Elisella and Nicella, become dominant. This continues beyond 55m which was the deepest observation made in this area.

At CL-1 no shallow reef features are found, with the exception of large isolated coral heads of Montastrea annularis between -3 and -8m. From -8 to -15m a sandy bottom with few scattered coral heads and rocky outcrops predominates. From -15m to the edge of the platform, the appearence is very similar to that described above for the Wreck Reef fore reef area, with a rim of rocky outcrops at the outer limits. These outcrops form coralline structures up to 7m high, and are also densely colonized.

At CL-2 on the central section of the atoll the shallow leeward margin is similar to that of CL-1, but deeper than -20m. The slope angle

changes from 15 to more than 55 degrees (Figs. 2 and 5). On this slope, coral patches are extremely abundant, forming a distinct hardground on the sandy slope. Coral biota, including scleractinian corals is very prolific and abundant on these patches. This habitat disappears at -51m due to another change in the angle of the slope, this time to less than 20 degrees. A deep layer of sand covers the slope, and sand eels (Nystactichthys halis) constitute the dominant fauna. At -61m the reef slope drastically changes to a near vertical wall, where sand falls were observed. Only sponges, a few non-symbiotic gorgonians and sea whips were found here.

On the northern end of the atoll at NL-1 area, the morphology and composition of the shallow margin, is similar to the one found on the central windward margin. But from -10m down to -25m the bottom slopes down at more than 35 degrees, and another ridge system is found on this slope (Fig. 4).

The ridges of this area, in sharp contrast with the other ridge systems, are not made of solid structures. Instead they are constituted by a dense, but ordered aggregation of independent, relatively small coral heads; resembling wide and low, loosely made ramparts. Although the sandy bottom of the slope can be observed from almost any place above the ridges, which are up to 2m high, sandy spaces are very narrow between the coral heads that constitute the ridge. This system, as all the others found on Chinchorro Atoll, shows a parallel layout between ridges which is perpendicular to the crest zone.

The widths of these rampart-like ridges ranges from 12 to 15m, and the distance between them exceeds the width of the ridges. Coral composition is again very rich and coral density is high, although distribution is patchy and is a function of available hard substrate, on the sandy slope. This community disappears at -25m due to a change in the bottom slope that gives place to an almost horizontal sand-covered platform, which extends all the way to the outer limit of the fore reef and drops to a near vertical slope, as in CL-1.

CHINCHORRO ATOLL AND OTHER CARIBBEAN ATOLLS

Species composition of corals and gorgonians of Chinchorro Atoll corresponds to that found elsewhere on the shallow reef environment of the Caribbean Sea (Goreau and Wells, 1967; Ross, 1971; Kinzie, 1973; Jordan, 1979, 1980; Jordan et al., 1981; Cairns, 1982; Muzik, 1982; Lasker and Coffroth, 1983). This may also be the case with respect to algae, marine vascular plants, and sponges.

Chinchorro Atoll shares with the southern Belize atolls the geological foundation upon which they rest and a similar set of environmental conditions, due to their close geographical position on the western Caribbean. Other Caribbean atolls that have been described, such as the ones found on the eastern shelf of Nicaragua (Milliman, 1969) are different in their basic morphology and possibly in their geological history as well. Alacran Reef in the Campeche Bank, on the Gulf of Mexico, also

shows a different basic morphology (Kornicker et al., 1959). However the coral communities and the general zonation patterns upon all these reefs, do not appear to differ greatly whenever similar environmental conditions predominate.

Regarding its general morphology, Chinchorro Atoll seems to be more similar to the exposed Glovers Reef and particularly to Lighthouse Reef, than to the protected Turneffe Islands on the Belize Atoll-complex. Although Chinchorro Atoll rests on the same submarine ridge as Turneffe Islands and is of approximately the same size, strong physiographic differences are found between both atolls. Most obvious is the large and complex mangrove and lagoon system that dominates the surface area of the Turneffe Islands: up to 25% of its total surface is covered by mangroves (Stoddart, 1962), whereas on Chinchorro Atoll the emerged areas, including the cays, amount to only 1% of its total area. The absence of patch reefs in the lagoonal area of Turneffe Islands (Stoddart, 1962) also marks a difference with Chinchorro Atoll.

Shallow spur and groove systems are well developed on Glovers Reef (James and Ginsburg, 1979) and also probably on Lighthouse Reef (Stoddart, 1962). Similar to those found on Chinchorro Atoll. The shallow spur and groove system of Chinchorro Atoll resembles those described by James et al., (1976), as shallow spur and grooves on the Belize barrier reef and Glovers reef; and also to a certain extent the high relief spur and grove system on Carrie Bow Cay (Rutzler and Macintyre, 1982b), also on the Belize barrier reef. It seems, however, that the complexity and variability of Chinchorro's spur and groove, and ridge systems has no parallel in the Belizean reef complex.

The fore reef beyond the spur and groove area of the windward side of Chinchorro Atoll differs drastically from the one described for Glovers reef and the barrier reef of Belize (James and Ginsburg, 1979; Rutzler and Macintyre,1982b). In the Belizean reefs coral growth is prolific at the base of the spur and groove system and the bottom of the fore reef steepens gradually but rapidly to an almost vertical wall at -50 to -60m. Whereas on Chinchorro Atoll there is an extense gently sloping platform descending at no more than 8 degrees from the base of the spur and groove system to approximately -40m, where a small increase on the steepness of the bottom was appreciated. A vertical or near vertical wall seems to exist beyond -60m (Fig. 2). This fore reef platform is similar to the one found along the eastern margin of the Yucatan Peninsula, where the distribution of coral reefs is largely related to the presence of the gently dipping fore reef platform (Jordan, 1980; Jordan et al., 1981).

Chinchorro's south to north depth gradient seems to be the result of some sort of differential accretion and/or accumulation of calcareous material, giving place to an apparently tilted atoll's platform. This apparent tilting, is evident on both the windward and leeward margins of the atoll. However, the deep water tongue on the lagoon zone, that runs south to north, may indicate no tilting of the Pleistocene basement. Tilting of the Pleistocene basement has been documented for the Belize Barrier Reef (Purdy, 1974; Purdy et al, 1975).

Lighthouse Reef in Belize also shows a depth gradient, although from west to east, which can actually be related to two different bottom levels, extending from the middle section of the atoll (Stoddart, 1962). Patch reefs are restricted to the deeper areas in both atolls.

According to the description of Glovers patch reefs by Wallace and Schafersman (1977), Chinchorro patch reefs are similar in terms of showing a zonation in response to the windward and leeward sides, as well as different biota assemblages, probably also related to the degree of exposure to wave action. Some differences may be simply related to patch size. The presence of an extensive reef flat between the reef crest and the lagoon on the windward side is a characteristic common to the Belizean and Chinchorro atolls. The abrupt transition of the rear reef flat to the lagoon floor is also a common characteristic.

The rim of the atolls on the leeward margin is probably the least differentiated feature in the four atolls. It is basically a reef flat that merges smoothly with the lagoon floor. This reef flat can be colonized by stretches of scleractinian corals forming a discontinuous and in most cases ephemeral crest, if any at all. Stoddart (1962) indicates the presence of spurs and grooves on the leeward of Lighthouse Reef, close to Northern Cay, a feature that may correspond to the ridge systems found on both the south and north ends of Chinchorro Atoll. These structures are most probably resulting from wave refraction on the extremes of the atoll. It is probable that they are also present on Glovers Reef. The response of spurs to refracted waves have been documented by several authors (Roberts, 1974; Sneh and Friedman, 1980).

It is considered that although some clear morphological differences exist between the Belize and Chinchorro atolls, these differences do not appear to be greater than the differences among the Belize Atolls, particularly those found between Glovers and Lighthouse Reefs with respect to Turneffe Islands. Although it is not known to what extent the development of Chinchorro Atoll followed a pattern similar to that of the Belizean atolls, its shape and general morphology, as well as its location upon a common submarine ridge with Turneffe Islands (Dillon and Vedder, 1973) suggest that Chinchorro may be considered as part of the Belizean reef-complex. However, until information from drilling is obtained, the origins of Chinchorro Atoll will remain unknown.

The gradual change in the general morphology and reef structures along the longest axis of Chinchorro Atoll is probably its most interesting characteristic, and seems to be related to the overall depth gradient along this axis. The effect of this gradual, but at the same time extensive change, strongly suggest that variability in the reef structures of the atoll are related to the morphology imposed by the underlying substrate and the exposure to wave action, on a depth gradient.

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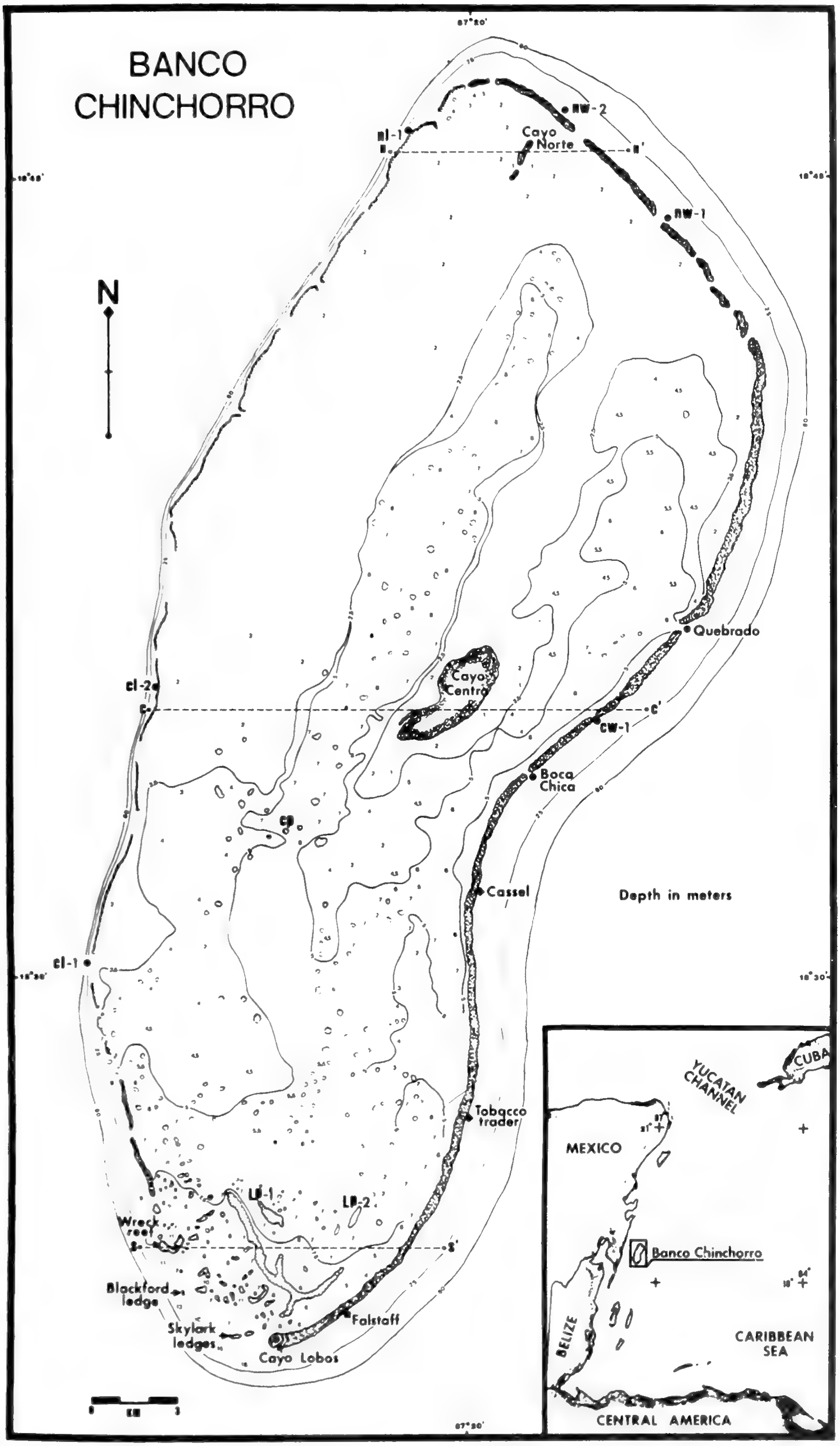

FIGURE 1.- Location and index map of Chinchorro Atoll. Drawing of the Atoll was based on a British survey in 1839, with minor modifications by the authors. Dotted lines mark bathymetric transects (Figure 9).

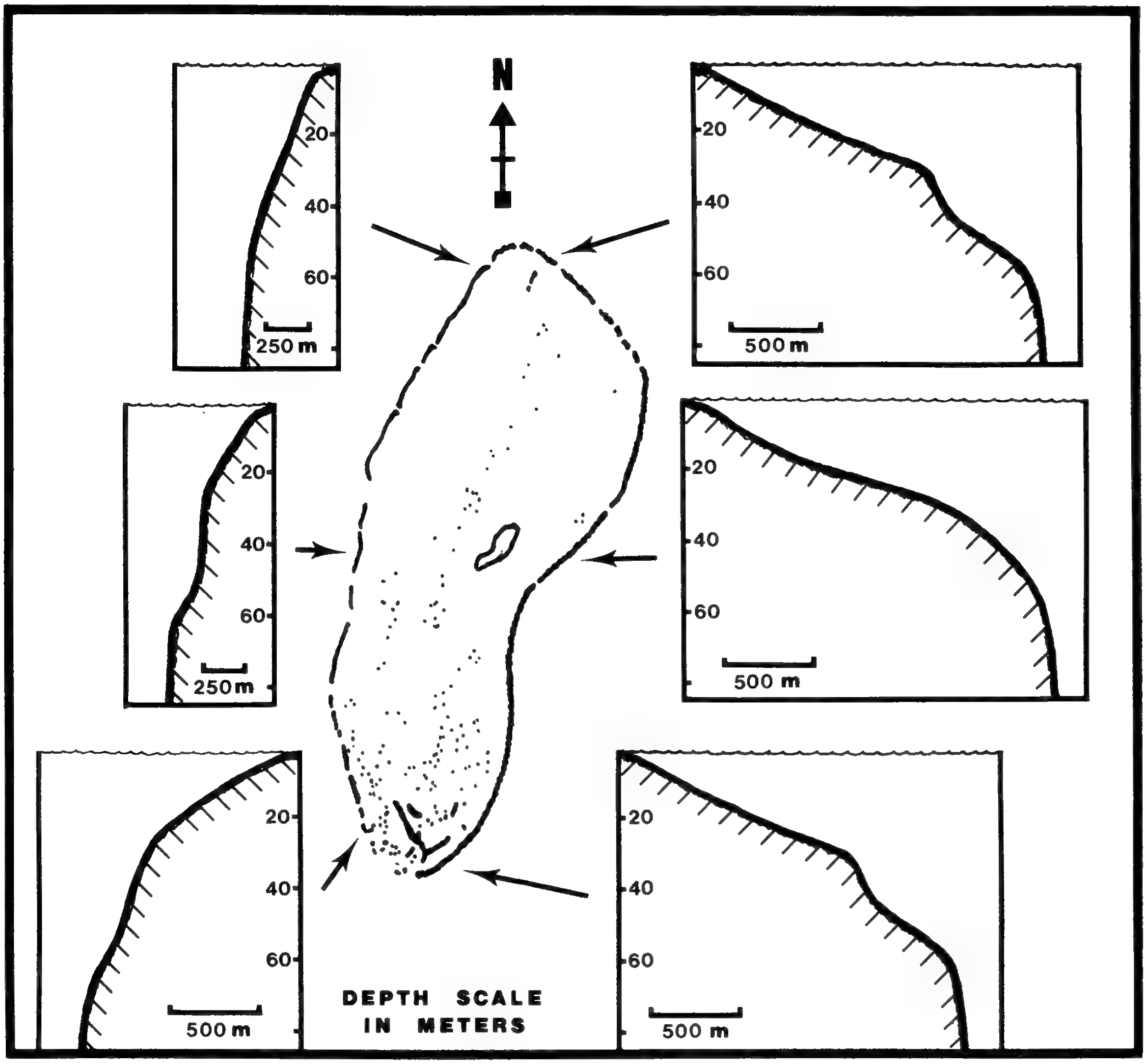

FIGURE 2.- Depth profiles of the fore reef zone on the south, central and north sections of Chinchorro Atoll, both in lee and windward sides (see Fig. 1 for spatial reference). Notice that vertical scale is exaggerated more than 10 times.

FIGURE 3.- Reef Crest at the southern section of the Atoll. The channel crosses from the rear reef zone towards the first set of spurs on the fore reef zone. Bottom depth is aproximately 1.5m.

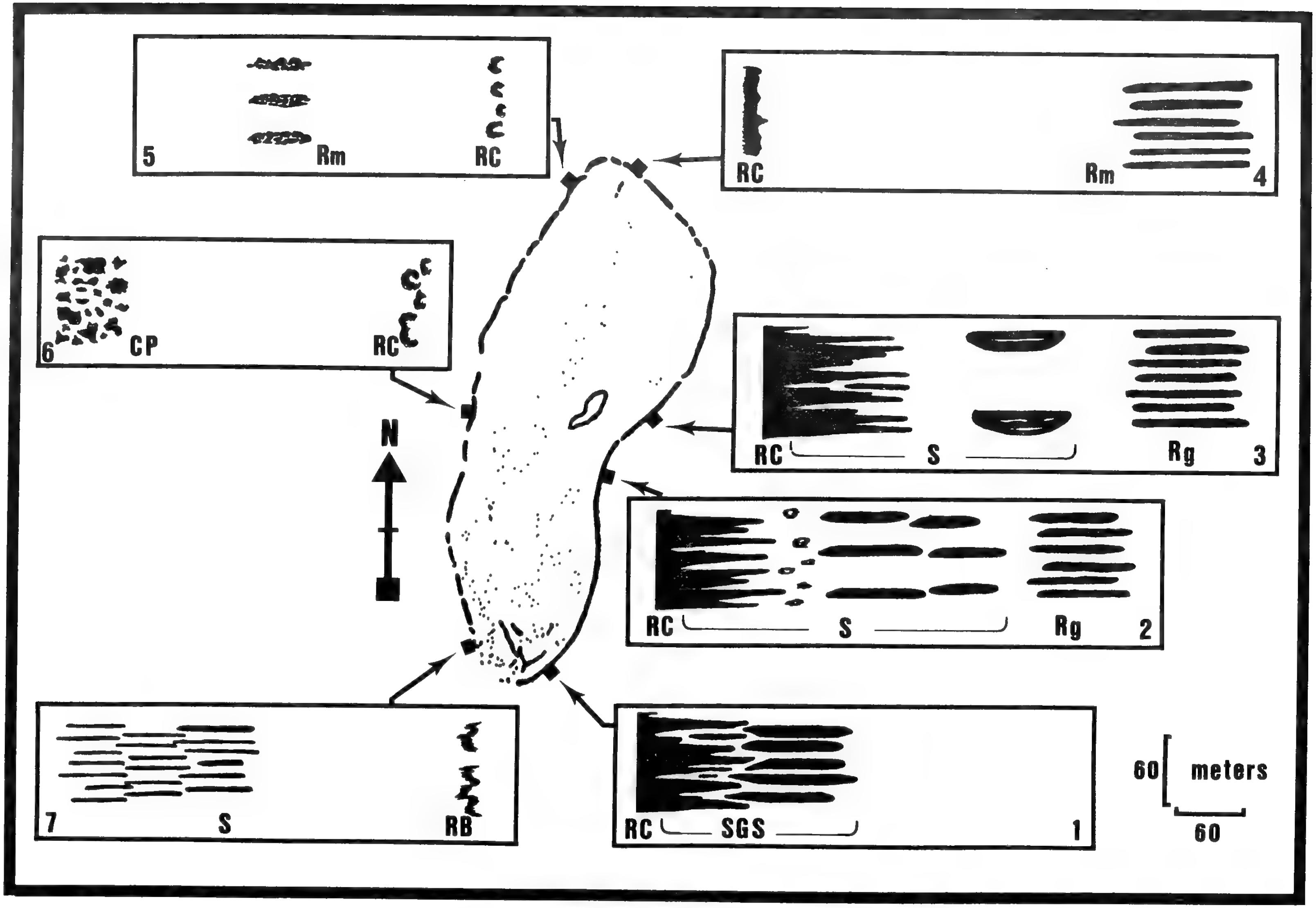

FIGURE 4.- Spur and groove systems, and ridge systems (see text) on Chinchorro Atoll. Plan view showing the layout and spatial distribution of the reef features, on different localities, both along the lee and windward margins of the atoll. SGS= spur and groove system; RC= reef crest zone; RB= rim bank; S= spurs; Rg= ridges on the outer fore reef zone; Rm= rampart-like spurs; CP= coral patch.

FIGURE 5.- Spurs of the first set, adjacent to the reef crest (see Figure 3). Depth is 4m to the bottom. The shape and surface of the spurs is rather irregular. The hydrocoral _Millepora complanata_ dominates the coralline fauna. The sides of the spurs are jagged and pitted, and there is no sand at the channel's bottom. Diver is 5' 11" tall.

FIGURE 6.- Spurs of the second set. Groove between two spurs filled with sand. The sides of the spurs are almost vertical and coral cover is very high, although masked by the fronds of the abundant gorgonians (<u>Gorgonia flabellum</u>). Depth at the bottom is 9m..

FIGURE 7.- Spurs of the second set. Seaward end of the spur, observe the abrupt end that is common in most spurs of the second and third sets. Coral cover is dominated by _Agaricia agaricites_ f. _carinata_ thickets. Depth at the base is 12m. Diver is 5′ 6" tall.

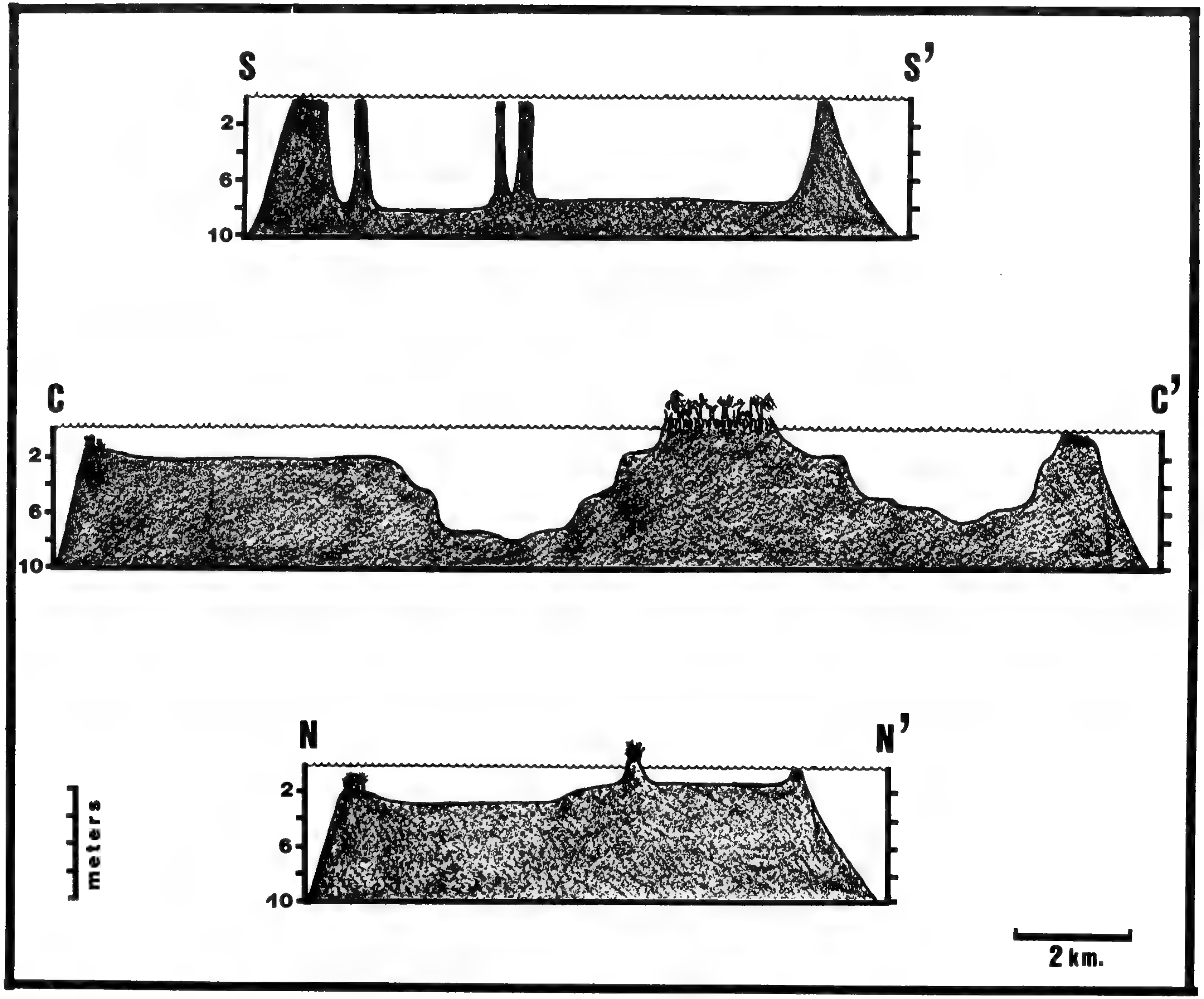

FIGURE 8 .- West to east bathymetric profiles on the south, central and north lagoon areas of Chinchorro Atoll. Transect location is shown in Figure 1. Observe that the lagoon bottom becomes shallower towards the north.

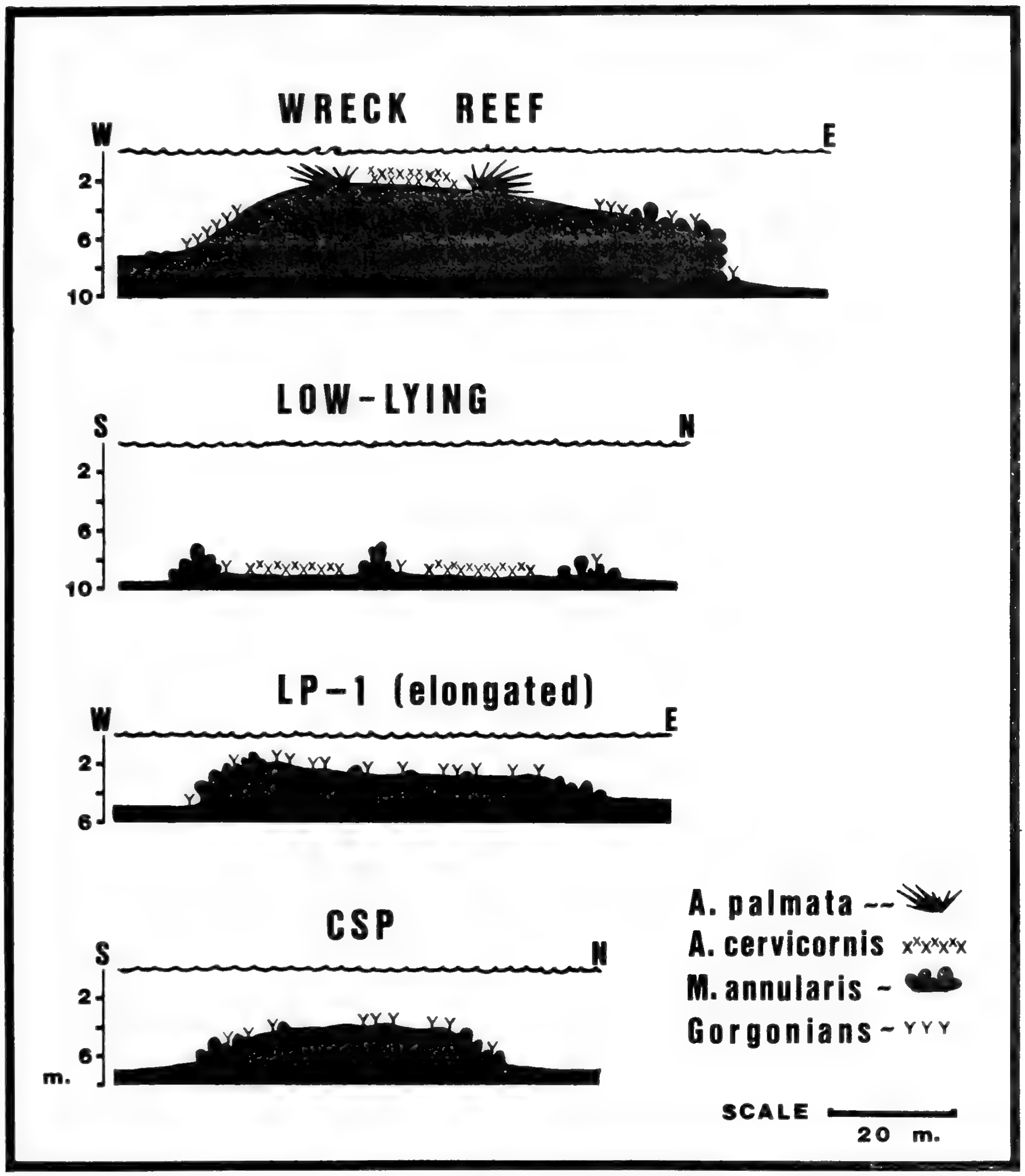

FIGURE 9.- Lagoon reef structures. Transverse profile of the main types of coral reef formations inside the atoll's lagoon. Wreck Reef represents rim banks. Low lying, refers to structures found on the southern end of the lagoon. LP-1 (elongated), refers to the elongated reefs inside the lagoon. CSP= central section patch reef.

Figure 10.- Large vase sponge (_Xestospongia muta_) at -30m on the southern leeward margin of the atoll. Diver is 5′ 8" in height.

Figure 11. Patch reefs on the lee of Chinchorro Atoll. Depth is 33m, observe the abundance of gorgonians and algae colonizing these patches at the edge of the atoll's platform.

TABLE 1.- Occurrence of scleractinian corals at different localities of Chinchorro Atoll. Hydrocorals of the genus Millepore are included in this list, because of their growth form and functional relationship to the reef structure. IFR= inner fore reef; OFR= outer fore reef; CZ= reef crest zone; RR= rear reef zone; PR= patch reefs; FR= fore reef zone; RB= rim banks.

SPECIES	WINDWARD			LAGOON	LEEWARD	
	IFR	OFR	CZ & RR	PR	FR	RB
Millepora alcicornis	x	x		x	x	x
M. complanata	x		x	x		x
M. squarrosa	x		x	x		x
Stephanocoenia michelinii		x			x	
Madracis decactis				x		
M. mirabilis		x		x		
Acropora palmata	x		x	x		x
A. cervicornis			x	x		x
A. prolifera			x			
Agaricia agaricites f. agaricites	x	x	x	x	x	x
A. agaricites f. purpurea	x	x	x	x	x	x
A. agaricites f. carinata	x			x		
A. agaricites f. humilis		x		x		
A. agaricites f. danai		x				
A. fragilis					x	
A. tenuifolia	x		x			x
A. lamarcki		x				
Leptoseris cucullata		x			x	
Siderastrea siderea	x	x		x	x	x
S. radians	x	x		x		x
Porites astreoides	x		x	x		x
P. porites	x	x	x	x	x	x
P. furcata				x		
P. divaricata			x	x		
Favia fragum	x		x	x		x
Diploria clivosa	x	x		x	x	x
D. strigosa	x	x		x	x	x
D. labyrinthiformis		x		x	x	
Manicina areolata		x		x		
Colpophyllia natans		x		x	x	
C. amaranthus				x	x	
Montastrea annularis	x	x	x	x	x	x
M. cavernosa	x	x		x	x	x
Solenastrea bournoni		x		x	x	
Meandrina meandrites		x		x	x	
Dichocoenia stokesi	x	x		x	x	x
D. stellaris				x		x
Dendrogyra cylindrus		x		x	x	x
Mussa angulosa		x		x	x	
Scolymia lacera		x				
S. cubensis		x			x	
Isophyllia sinuosa	x	x		x	x	x
Isophyllastrea rigida	x	x	x	x	x	x
Mycetophyllia lamarckiana		x		x	x	
M. aliciae		x				
M. danaana		x			x	
M. ferox		x				
Eusmilia fastigiata	x	x		x	x	x

TABLE 2.- Occurrence of gorgonian species on different localities of Chinchorro Atoll. IFR= inner fore reef; OFR= outer fore reef; CZ= reef crest zone; RR= rear reef zone; PR= patch reefs; FR= fore reef zone; RB= rim banks.

SPECIES	WINDWARD			LAGOON	LEEWARD	
	IFR	OFR	CZ & RR	PR	FR	RB
Erythropodium caribaeorum		x			x	x
Iciligorgia schrammi		x			x	
Briareum asbestinum	x		x	x	x	x
Gorgonia flabellum	x	x	x	x	x	x
G. mariae		x				
G. ventalina		x		x		x
Lophogorgia sp.	x	x				
Pterogorgia anceps	x	x		x		x
P. citrina	x	x		x		x
P. guadalupensis		x				
Pseudopterogorgia acerosa		x		x	x	x
P. americana	x	x	x	x	x	x
P. rigida		x				
P. kallos				x		x
Pseudopterogorgia sp.					x	
Eunicea laciniata		x		x		x
E. calyculata	x	x		x	x	x
E. laxispica					x	
E. mammosa	x	x	x	x	x	x
E. tourneforti	x	x		x	x	x
Eunicea sp. 1		x				
Eunicea sp. 2					x	
Muricea atlantica		x		x	x	x
M. elongata					x	
M. muricata		x		x	x	x
M. pinnata		x			x	
Muriceopsis flavida	x	x	x	x	x	x
Plexaura flexuosa	x	x	x	x	x	x
P. homomalla	x	x	x	x	x	x
Plexaurella dichotoma	x	x	x	x	x	x
P. grisea		x			x	
P. nutans		x				
Plexaurella sp. 1		x				
Plexaurella sp. 2				x		
Pseudoplexaura porosa	x	x	x	x	x	x
P. flagellosa		x		x	x	x
Ellisella barbadensis		x				
E. elongata		x				
Nicella schmitti					x	

ATOLL RESEARCH BULLETIN

NO. 311

A BIBLIOGRAPHY OF PLANT CONSERVATION IN THE PACIFIC ISLANDS: ENDANGERED SPECIES, HABITAT CONVERSION, INTRODUCED BIOTA

BY

ROBERT A. DEFILIPPS

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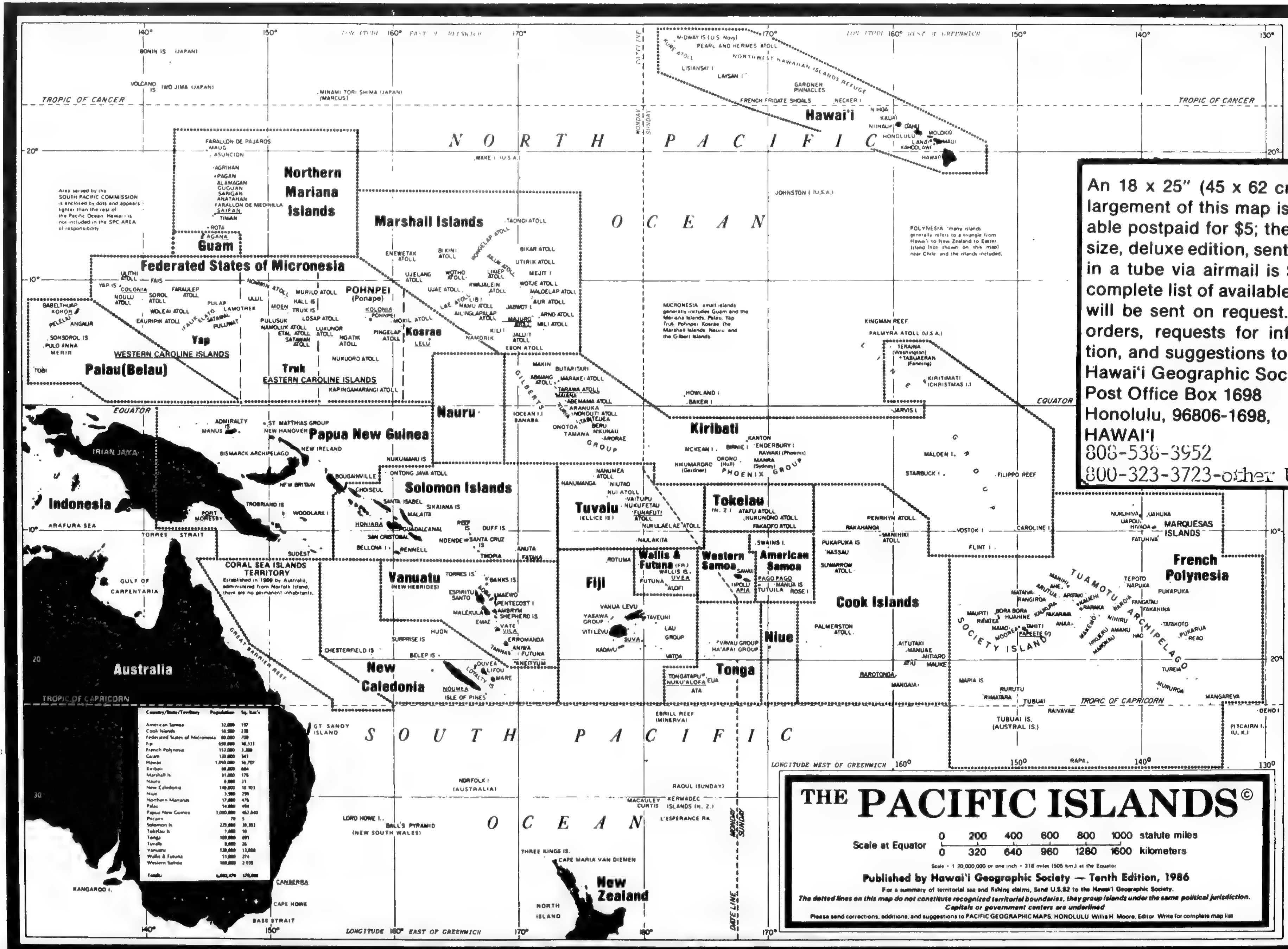

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A BIBLIOGRAPHY OF PLANT CONSERVATION IN THE PACIFIC ISLANDS: ENDANGERED SPECIES, HABITAT CONVERSION, INTRODUCED BIOTA

BY

ROBERT A. DEFILIPPS

Introduction

To plant conservationists who must fervently gather botanical intelligence against a time-frame of rapidly dwindling plant populations and habitats, the following statements expressed by M.-H. Sachet and F.R. Fosberg (1955, 1971) are both pertinent and self-explanatory:

> "The great unsolved problem of modern scientific methodology is that of bibliography, that of knowing what has been accomplished already. In starting any line of investigation the scientist is faced with the choice of ignoring his predecessors, possibly wasting much time on work that has already been done and missing valuable information and ideas, or of spending a large proportion of his time in study of current and past literature on the field. The latter alternative is preferable from almost any viewpoint, though the amount of time involved makes it very expensive...Any worker who, for his own investigation, explores the literature of a field with some thoroughness may do his colleagues a useful service if he presents the results of such a search in the form of an annotated bibliography. His familiarity with the contents of the papers examined may enable him to save later workers an enormous amount of time by indicating very briefly what the paper is, whether it contains original information and what aspect of the field is covered."

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Several large regions of the world are plagued by conservation problems shaped around a particular inherent set of geographical, biological and human conditions which have been operational for varying periods of time. Typical of situations facing Latin America are the progress of economic development in Amazonia with its attendant loss of rainforest biodiversity, and the Central American "hamburger connection" involving conversion of forests to grazing land to support the export of cheap beef to the United States. Characteristic of Africa is the struggle with desertification in the Sahel and the terminally desperate fuelwood crisis there. Europe has its centuries-long history of urbanization and the deforestation of Mediterranean lands to contend with, while the similarly industrialized North American continent must deal with large-scale wetland drainage, the effects of high-technology terrain vehicles (swamp buggies, dune buggies, snowmobiles, motorcycles) on the landscape, as well as protecting the endangered cacti indigenous to the deserts from overexploitative commerce.

The 7,500 islands of the Pacific Ocean share a unifying theme in connection with environmental and ecological disturbances, for their island ecosystems are very sensitive and fragile, and easily susceptible to irreversible vegetational and erosional damage as caused by weeds, feral animals, and humankind. As noted by Arthur Dahl (1986), "The total land area of Oceania is very small, but the region has the world's highest proportions of endangered species,...and probably endemic species, per unit area or per inhabitant." In addition to the specialized and endangered flora of such isolated Pacific ecosystems, which are partly within the Cretaceous cradle of evolution of the first, primitive flowering plants, the Pacific islands usher us into their uniqueness by means of consideration of the sandalwood trade, the phenomenon of mass dieback of forests, the practice of total conversion of islands into coconut plantations for the copra trade, the impact of military operations during World War II, studies of radioactivity levels and nuclear detonations on the remote shores of selected atolls, and the serious degradation of the incomparably beautiful and productive coral reefs by crown-of-thorns starfish and silt from accelerated terrestrial erosion.

The geographical scope of this bibliography, on which research was concluded in May 1987, encompasses Micronesia, Polynesia and Melanesia, with boundaries including Clipperton, Cocos, Galapagos, Easter and Juan Fernandez Islands in the eastern Pacific; Norfolk, Lord Howe, New Hebrides, Bismarck, and Admiralty Islands in the south and western reaches of the ocean, and northwards to the Ryukyu and Bonin (Ogasawara) Islands. The coverage excludes a number of islands which are in a comparatively close proximity to

mainland, such as Japan, the Philippines, Borneo, and New Guinea, as well as the more distant and very large islands comprising New Zealand.

A number of people deserve my grateful thanks for their encouragement and assistance during this project. In the Department of Botany, Smithsonian Institution, I wish to thank Dr. F. Raymond Fosberg, Dr. Marie-Helene Sachet, Dr. Mark M. Littler, Royce Oliver; staff of the Plant Conservation Unit, S. Jane Villa-Lobos, Shirley L. Maina, and Olga Herrera-MacBryde; technical aid from Kim Barker, Karen Lee, Chris Tuccinardi and Marie Uehling; and botany interns Jeff Nekola and Orlo C. Steele for contributions to the geographical index and annotations, respectively. I would also like to acknowledge the help of Marsha Sitnik, Office of the Director, National Museum of Natural History, for supplying data on the Galapagos. I am particularly indebted to S. Jane Villa-Lobos for her critical assistance with computerization of the manuscript. Persons who also extended courtesies and supplied references include Mrs. Ruth F. Schallert (Librarian), Stephen D. Davis (IUCN Conservation Monitoring Centre, Threatened Plants Unit, Royal Botanic Gardens, Kew), Dr. Gustav Paulay (University of Washington, Seattle), and Dr. David S. Liem (Derwood, Maryland).

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Albert, H. 1986. Structure of a disturbed forest community replanted with Eucalyptus robusta on Wai'alae Ridge, Oahu, Hawaii. Newsletter Hawaiian Botanical Society 25 (2): 60-69.
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Amerson, A. B. 1971. The natural history of French Frigate Shoals, northwestern Hawaiian Islands. Atoll Research Bulletin 150: 1-383.
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Amerson, A. B. 1973. Ecological Baseline Survey of Johnston Atoll, Central Pacific Ocean. 365 pp. Washington, D.C.: Ecology Program, Smithsonian Institution.
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Amerson, A. B., Clapp, R.B. and W.O. Wirtz. 1974. The natural history of Pearl and Hermes Reef, northwestern Hawaiian Islands. Atoll Research Bulletin 174: 1-306.

The atoll is part of the Hawaiian Islands National Wildlife Refuge. On Southeast Island, ironwood (Casuarina) trees were planted by the U.S. Navy in 1963 to increase the island's visibility from the ocean. As this was in violation of Refuge regulations, all trees not already dead were destroyed in 1964.

Amerson, A.B. and P.C. Shelton. 1976. The natural history of Johnston Atoll, Central Pacific Ocean. Atoll Research Bulletin 192: 1-479.
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Amerson, A.B., Whistler, W.A. and T.D. Schwaner. 1982b. Wildlife and Wildlife Habitat of American Samoa. II. Accounts of Flora and Fauna. 151 pp. Washington, D.C.: U.S. Fish and Wildlife Service.
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Maui, Molokai, Hawaii) 25,000 native trees, and the following amounts of introduced species: 119,000 Australian toon (Toona australis); 164,000 slash pine (Pinus elliottii); 816,000 rosegum (Eucalyptus grandis); and 962,000 saligna (Eucalyptus saligna).

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Announcement of a survey list to be prepared by Subcommittee on Nature Protection of the Standing Committee on Pacific Botany, Pacific Science Association.

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Seeds of ohia (Sesbania tomentosa) and other endangered Hawaiian plants have been planted on the Bishop Museum grounds in Honolulu, in hopes of preserving the species.

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Concerns the Pacific Tropical Botanical Garden, whose mission is to grow endangered species.

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Includes, from Hawaiian Islands, *Lipochaeta venosa*, *Haplostachys haplostachya* var. *angustifolia*, *Stenogyne angustifolia* var. *angustifolia* and *Kokia cookei*.

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Concerns *Euphorbia skottsbergii* var. *kalaeloana*.

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New record of this plant for Rota; previously known only from four trees on Guam.

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Incipient danger in proposed development of Henderson Island.

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Deforestation of Easter Island may have led to the collapse of the island's civilization. Loss of soil fertility as a result of deforestation may have undermined food production and caused out-migration of people. Sophora toromiro, the only Easter Island endemic plant, is extirpated in the wild.

Anonymous. 1985a. Koke'e logging: "maintenance"?. Elepaio 45(12): 131-132.
400 koa trees to be cut in Koke'e State Park, jeopardizing the most diverse mesic forests in Hawaii.

Anonymous. 1985b. Ohi'a woodchipping double talk. Elepaio 45(12): 132-134.
Deprecates the continuance of woodchipping in the United States' last lowland tropical forest, in Hawaii.

Anonymous. 1985c. Plan approved for three songbirds of the northwestern Hawaiian Islands. Endangered Species Technical Bulletin 10(2): 8-10.
Notes that the fragile ecosystem of Laysan Island was severely damaged early in this century after introduced rabbits multiplied and consumed virtually all the vegetation, resulting in a wasteland. As a direct result of this, several endemic terrestrial birds became extinct: the Laysan millerbird (Acrocephalus familiaris familiaris),Laysan honeycreeper (Himatione sanguinea freethi), and Laysan rail (Porzana palmeri).

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Anonymous. 1985e. Northern Islands slated for preservation. Coastal Views(Saipan,Marianas) 7(2): 1,3,10; see also op. cit.7(3): 1,8-9 (1985).
Describes, with photos, four islands in Northern Marianas which will be given conservation protection status: Maug, Uracas, Asuncion, and Guguan. The island of Farallon de Medinilla, which is regularly bombed and strafed as a target range under the military lease agreement with the United States, is no longer considered a candidate for preservation.

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Anonymous. 1986b. Two plants given final Endangered Species Act protection: Lanai sandalwood or 'iliahi. Endangered Species Technical Bulletin 11(2): 3.
Concerns Santalum freycinetianum var. lanaiense, of which only 39 individuals remain on Lanai (Hawaiian Islands). Introduced rats prey on its fruits, and it is also subjected to severe ecosystem disturbances.

Anonymous. 1986c. Found again. Species (Newsletter of IUCN-Species Survival Commission) 6: 20.
Formerly presumed extinct, Abutilon julianae (Malvaceae) from Norfolk Island was last recorded in 1912, but it was recently discovered on Philip Island, where vegetation once devastated by goats, pigs and rabbits is now regenerating.

Anonymous. 1986d. Recovering the Galapagos. IUCN Bulletin 17(4-6): 77.
"The IUCN, in cooperation with the Charles Darwin

Foundation, is attempting to reduce the threat posed to the Galapagos Islands native species by dozens of species introduced by man." Santiago Island still has the serious problem of 100,000 goats and 20,000 pigs.

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A single common mullein plant (Verbascum thapsus) has been found near roadside at 9000 ft., and park employees are wary that potential infestation can be controlled.

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"It is clear that certain areas on Midway are being damaged for continued Navy use and altered for other uses. The cross runway is being invaded rapidly by ironwood (Casuarina). The runway aprons are almost completely invaded and root-heaving of the pavement by ironwood will probably destroy the runway in the 1980's. Similar problems are far more advanced on the Eastern Island runways."

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Relates history and controversy over introduction of axis deer in Hawaiian Islands.

Atkinson, I.A.E. 1977. A reassessment of factors, particularly Rattus rattus L., influencing the decline of endemic forest birds in the Hawaiian Islands. Pacific Science 31(2): 109-113.
Includes section on introduced browsing mammals (cattle, horses, sheep, goats, English pigs) whose devouring of vegetation affected the food supply of the birds.

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Ayensu, E.S., Heywood, V.H., Lucas, G.L. and R.A. DeFilipps. 1984. Our Green and Living World: The Wisdom to Save It. 255 pp. Washington, D.C.: Smithsonian Institution Press.
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Bakus, G.J. 1975. Marine zonation and ecology of Cocos Island, off Central America. Atoll Research Bulletin 179: 1-9.
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Baldwin, P.H. and G.O. Fagerlund. 1943. The effect of cattle grazing on koa reproduction in Hawaii National Park. Ecology 24: 118-122.
Deleterious effects of cattle on Acacia koa.

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Caledonia that potentially could be grown commercially for medicinal purposes.

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Cryptostegia grandiflora(Asclepiadaceae), the "Indian rubber vine", is invading pastures of western New Caledonia.

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"In many islands one finds at altitudes varying between 1,500 and 2,400 feet, vast grassy patches containing graminaceae (sic) and ferns of the Gleichenia type. These represent the final stage of the severe degradation of the vegetation caused by man and animals introduced since the arrival of the white man. This degradation often goes hand in hand with bad soil erosion."

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Barrau, J. 1960b. The sandalwood tree. South Pacific Bulletin 10(4): 39, 63.
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Barrau, J. 1967. Les hommes, les plantes et la mer en Oceanie tropicale. Cahiers du Pacifique 10: 59-78.
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Barrau, J. 1983. La diffusion humaine des vegetaux et des animaux envisagee d'un point de vue biogeographique. C.

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Most of Batiki once supported a tree cover; now there is dense weedy covering in a fire-climax vegetation.

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Gives location of introduced *Eucalyptus* groves.

Berger, A.J. 1966. Save Hawaii's unique flora and fauna. Elepaio 27(1): 1-2.
Imputes lack of conservation effectiveness to the State reforestation activities; article followed by rebuttal by Governor Burns.

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Includes discussion of habitat destruction caused by sugarcane cultivation, sandalwood harvests, and invasive tropical weeds (*Lantana, Myrica, Rubus, Opuntia*).

Berger, A.J. 1975a. The Hawaiian honeycreepers, 1778-1974. Elepaio 35 (10): 110-118.
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Bryan, E.H. 1949. Economic Insects of Micronesia. 29 pp. Washington, D.C.: National Research Council.
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Bryan, L.W. 1947. Twenty-five years of forestry work on the island of Hawaii. Hawaiian Planters' Record 51(1): 1-80.
Includes photos of introduced trees and revegetation projects, also of roundups of feral sheep and goats.

Bryan, L.W. 1971. Native Hawaiian plants. Newsletter

Hawaiian Botanical Society 10(4): 38-42.
Observations on numerous threatened endemic species.

Bryan, L.W. 1973. Ahinahina. Newsletter Hawaiian Botanical Society 12(1): 1-2.
On the decline and protection of *Argyroxiphium sandwicense*, the silversword or ahinahina (Compositae).

Buck, M. 1984. The precious forests of Ponape and Kosrae. Glimpses of Micronesia 24(3): 24(3): 33-37.
A forest inventory is being undertaken to provide baseline data or a starting point to monitor the effect of the current period of Micronesian cultural transition, growth, and change, on the forest resource.

Budowski, G. 1972. Book review, of Wiggins, I.L. and D.M. Porter, 1971, Flora of the Galapagos. IUCN Bulletin 3(10): 50.
Review is critical of the book's casual remark that the El Junco lake area on San Cristobal Island might support carefully planned, limited agricultural activity.

Bunge, F.M. and M.W. Cooke. 1984. Oceania, A Regional Study. 550 pp. Washington, D.C.: Headquarters, Department of the Army.
Includes useful background overview of the region.

Burcham, L.T. 1948. Observations on the grass flora of certain Pacific islands. Contributions United States National Herbarium 30(2): 405-447.
On Peleliu I. (Palau Is.), "virtually all vegetation was denuded from the western and southern portions by our (military) operations. However, configuration of the terrain and nature of the coral bedrock are such that this denudation should produce no erosion problems; as a matter of fact, the net result of these activities should be to accelerate soil formation."

Byrne, J.E., ed. 1979. Literature Review and Synthesis of Information on Pacific Island Ecosystems. Washington, D.C.: U.S. Fish and Wildlife Service, Office of Biological Services.
Contains articles by various authors concerning status of ecosystems in the Pacific.

Calvopina, L.H. and F. Calvopina. 1980. Reproductive biology of wild goats and growth and development of vegetation in permanent goat exclosures on Isla San Salvador (Santiago), pp. 87-97, in Annual Report 1980, Charles Darwin Research Station. Santa Cruz Island, Galapagos, Ecuador.
An objective of this project is to establish exclosures to protect endangered plants until goats can be brought under control or eradicated.

Calvopina, L.H. and T. DeVries. 1975. Estructura de la poblacion de cabras salvajes (Capra hircus L.) y los danos causados en la vegetacion de la Isla San Salvador, Galapagos. Rev. Universidad Catolica 3(8): 219-241.
Concerns the structure of the wild goat population and the damage caused to vegetation on San Salvador Island, Galapagos.

Campbell, D.J. and M.R. Rudge. 1978. Reply to: Goats on Auckland Islands. New Zealand Journal of Botany 16(2): 293-296.
Instructive for its approach to the feral goat problem in general.

Campbell, E.M.J. 1952. Land and population problems in Fiji. Geographical Journal 118(4): 477-482.
Population pressure impacts land adversely.

Campon, R. 1982. Additional Reading. Natural History 91(12): 88-89.
The December 1982 special issue of Natural History on Hawaii: Showcase of Evolution presents many interesting articles, and supplementary reading suggested by Campon covers the major topics.

Canby, T.Y. 1984. El Nino's ill wind. National Geographic 165(2): 144-183.
Explains causation of storms damaging vegetation, including picture of 1983 cyclone on Aruta Atoll, Polynesia, which arose due to El Nino.

Canfield, J.E. 1981. Palau: diversity and status of the native vegetation of a unique Pacific island ecosystem. Newsletter Hawaiian Botanical Society 20: 14-20.
Human disturbance factors include the historical burning of uplands, extensive cultivation of lowlands, mining and war damage, and the recent influx of weedy introductions.

Carew-Reid, J. 1984. The South Pacific Regional Environment Program. Ambio 13(5-6): 377.
General description of the program.

Carlquist, S. 1965. Island Life. 451 pp. Garden City, New York: Natural History Press.
Includes plant endemism, adaptation to island ecosystems, archipelago effects.

Carlquist, S. 1970. Hawaii: A Natural History. 463 pp. Garden City, New York: Natural History Press.
Includes biological phenomena relevant to plant conservation such as dispersal, loss of competitiveness, adaptation, breeding systems; special discussions on lobelioids, silverswords, extinction, and conservation.

Carlquist, S. 1974. Island Biology. 600 pp. New York: Columbia University Press.
Evolutionary processes and patterns in island biota, e.g. Hawaii, New Caledonia, Galapagos, and Juan Fernandez Islands.

Carlquist, S. 1982a. The first arrivals. Natural History 91(12): 20-22, 24, 26, 28,30.
Chance and deliberate dispersals of plants and animals to the Hawaiian Islands are described.

Carlquist, S. 1982b. Hawaii: a museum of evolution. The Nature Conservancy News 32(3): 4-11; Bulletin Pacific Tropical Botanical Garden 13(2): 33-39 (1983).
Includes discussion of threats to the vulnerable flora, such as feral mammals.

Carlson, N.K. 1954. The vanishing fishponds of Molokai. Natural History 63: 248-254.
Ponds are silting-up, due to increased soil erosion on slopes caused by overgrazing and destruction of vegetation.

Carlson, N.K. 1973. The Kamehameha Schools-Bernice Pauahi Bishop Estate and the forests of the Big Island. Newsletter Hawaiian Botanical Society 12(3): 16-19.
A conservationist offers alternative viewpoint to total preservation of Hawaiian forests.

Carpenter, R.W. 1959. Maui notes. Elepaio 20(1): 1.
Concerning the feral goats, Park Naturalist Carpenter cheerfully observes that "with all the damage they do, they are interesting to watch and may be seen most anywhere in the crater, and especially on the cliffs, in herds of from 3 or 4 to 30 or 40".

Carr, G.D. Undated, unpublished manuscripts. Status reports on Argyroxiphium sandwicense DC. var. sandwicense (Asteraceae); Santalum freycinetianum Gaud. var. lanaiense Rock (Santalaceae); Scaevola coriacea Nutt. (Goodeniaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Carr, G.D. 1982. Unpublished manuscripts. Status reports on Dubautia herbstobatae Carr (Compositae); Dubautia latifolia (Gray) Keck (Compositae); Wilkesia hobdyi St. John (Compositae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Carr, G.D. and J.K. Baker. 1977. Cytogenetics of Hibiscadelphus (Malvaceae): a meiotic analysis of hybrids in Hawaii Volcano National Park. Pacific Science 31(2):

191-194.
Hybridization can cause concern for the integrity of taxa. Refer to article by J.K. Baker and S. Allen (1977).

Carr, G.D., Robichaux, R.H. and D.W. Kyhos. 1982. Radiating silverswords. Natural History 91(12): 36-39.
Variation, evolution, adaptive radiation in Hawaiian Compositae of the genera *Argyroxiphium*, *Dubautia*, and *Wilkesia*.

Carson, H.L. 1982a. Hawaii: showcase of evolution, an introduction. Natural History 91(12): 16-18.
Hawaiian biota are mentioned.

Carson, H.L. 1982b. A cloudy future. Natural History 91(12): 72.
"Energy needs in the 1980's have generated new threats to natural areas (of Hawaii), especially to the rain and cloud forests that are still not deeply penetrated by agriculture."

Carter, W. 1940. A neglected aspect of land utilization in Hawaii. Proc. Sixth Pacific Science Congress 4: 903.
It is suggested to convert suitable forest lands to smallholder fruit and nut crops, e.g. cashew nuts in upper forests, and coconuts in coastal areas, to augment the Hawaiian food supply, and to quinine plantations for strategic medicine.

Catala, R.L.A. 1953. Protection de la nature en Nouvelle-Caledonie. Proc. Seventh Pacific Science Congress 4: 674-679.
In New Caledonia, native and naturalized weeds are rupturing the equilibrium of the land.

Caufield, C. 1985. In The Rainforest. 304 pp. New York: Alfred A. Knopf.
Makes reference to Unilever timbering in the Solomon Islands.

Caum, E.L. 1936. Notes on the flora and fauna of Lehua and Kaula islands. Occasional Papers, B.P. Bishop Museum 11(21): 3-17.
Lehua is overrun by rabbits and *Lantana camara*. Aubrey Robinson, owner of island of Niihau, is systematically exterminating the lantana on Lehua to prevent its spread to Niihau (Hawaiian Islands).

Chamberlain, P. 1972. Micro planning. Micronesian Reporter 20(2): 33-43.
Account of 1972 master planning for Wotje Atoll in the Marshall Islands; includes 1944 aerial photo of the heavily bomb-cratered island.

Chand, V. and S. Chand. 1980. Medicinal plants of Fiji with special attention to the antifertility plants, p. 235, in Fourth Asian Symposium on Medicinal Plants and Spices. Abstracts. Bangkok: Government of Thailand and Unesco.
An assessment of the traditionally used antifertility plants will attempt to discover their potential as a medicinal source in the Fijian fertility regulation program, since, although family planning is an important program in the nation, abortion is not yet legalized.

Chapline, W.R. 1961. FAO's interest in forest, range and watershed conservation in the Pacific area. Proc. Eighth Pacific Science Congress 6: 226-232.
Recommends studies to develop sound policies of forest grazing, e.g. reseeding forests that have deteriorated due to grazing animals, with native or exotic grasses.

Chapman, M.D. 1985. Environmental influences on the development of traditional conservation in the South Pacific region. Environmental Conservation 12(3): 217-230.
It is suggested that environmental factors such as predictability and extremeness could account for some of the fundamental differences in conservational attitudes observed in different traditional societies. Quite elaborate intentional conservation measures and regulations were in effect on Pukapuka and Tahiti in the old days.

Chapman, V.J. 1967. Conservation of maritime vegetation and the introduction of submerged freshwater aquatics. Micronesica 3: 31-35.
Appropriate cautionary measures must be observed with any introductions.

Chapman, V.J. 1969. Conservation of island ecosystems in the South-West Pacific. Biological Conservation 1: 159-165.
Includes descriptions of some species and vegetation types meriting preservation.

Char, W. 1976. Field studies of the *Sesbania* complex on the island of Hawaii. Bulletin Pacific Tropical Botanical Garden 6(2):41.
Sesbania tomentosa is subjected to cattle browsing damage at South Point (Ka Lae).

Char, W.P. and N. Balakrishnan. 1979. 'Ewa Plains Botanical Survey. Honolulu, Hawaii: University of Hawaii at Manoa. U.S. Department of the Interior Contract Report.
Includes status of *Abutilon menziesii* and many other endemics.

Chave, E.H. and J.E. Maragos. 1973. A historical sketch of the Kaneohe Bay region, pp. 9-13, in Smith, S.V., et al., eds., Atlas of Kaneohe Bay: A Reef Ecosystem Under Stress. 128 pp. Honolulu, Hawaii: University of Hawaii Sea Grant Program.
Population increase, urbanization, replacement of native vegetation by weeds and other introductions, and grazing which facilitated increased erosion and sediment loading in streams, are among causes of deterioration of the ecosystem. The effects of nutrient stresses on the biota include diminishment of algae in the south Bay, and an enormous growth of the "bubble alga", Dictyosphaeria, in mid-Bay.

Cheatham, N.H. 1968. Forestry and conservation in the Trust Territory of the Pacific Islands. South Pacific Bulletin 18(4): 38-41, 47.
Notes certain problems such as indiscriminate burning of the grassland areas on Babelthuap Island.

Cheatham, N.H. 1975. Land development: its environmental impact in Micronesia. Micronesian Reporter 23(3): 7-11.
"When planners consider various approaches to land development, they should weigh the estimated ecological impacts and choose alternatives that have the least detrimental impact on the environment."

Chevalier, J.-P., Denizot, M., Mougin, J.-L., Plessis, Y. and B. Salvat. 1968. Etude geomorphologique et bionomique de l'Atoll de Mururoa (Tuamotu). Cahiers du Pacifique 12: 1-144.
A section on flora and vegetation mentions the adventive plants on this French nuclear testing ground.

Chilcott, M. 1986. Australian plants campaign. Threatened Plants Newsletter (IUCN) 16: 6-8.
Includes discussion of project on conservation biology of the endangered Hibiscus insularis, a plant reduced to 8-10 living individuals in two small thickets on Philip Island, where its survival is threatened by rabbits.

Chock, A.K. 1963. Kokee. Newsletter Hawaiian Botanical Society 2(3): 37-39.
Kokee, where much of the endemic vegetation of Kauai is found, is partially being overrun by invasive exotic weeds such as blackberry, firebush, Malabar melastome, and lantana.

Christensen, B. 1983. Mangroves- what are they worth? Unasylva 35(139): 2-15.
Ecological significance of mangroves is discussed.

Christensen, C. 1979. Propagating Kauai's Brighamia. Bulletin Pacific Tropical Botanical Garden 9(1): 2-4.

Brighamia citrina var. napaliensis (Lobeliaceae), from the Na Pali cliffs of Kauai, in the first Brighamia ever to flower in cultivation.

Christensen, C.C. 1982. Hawaiian land snails: past, present, and (?) future. Ka 'Elele 9(2): 3.
"Land clearance for agriculture and deforestation by cattle or other means have resulted in the extinction of many species that were dependent on native vegetation."

Christensen, C.C. and P.V. Kirch. 1981. Nonmarine mollusks from archaeological sites on Tikopia, southeastern Solomon Islands. Pacific Science 35(1): 75-88.
Since the year 900 BC, mankind has cleared land for agricultural purposes on Tikopia, resulting in displacement of native vegetation. Then, interisland transport of economic plants by humans provided opportunities for the introduction of adventive terrestrial mollusks, of which three species are known to have become established there as of 900 BC.

Christian, K.A. and C.R. Tracy. 1980. An update on the status of Isla Santa Fe since the eradication of the feral goats. Noticias de Galapagos 31: 16-17.
On this island in the Galapagos, native vegetation appears denser and more diverse since feral goats were exterminated.

Christophersen, E. and E.L. Caum. 1931. Vascular plants of the Leeward Islands, Hawaii. B.P. Bishop Museum Bulletin 81: 1-41.
Relates history of rabbit swarms on Laysan Island, which denuded the terrain.

Cieply, M. 1983. East of Eden. Forbes (31 January): 34-36.
Tough economic considerations of Hawaiian land use are discussed.

Clapp, R.B., Kridler, E. and R.B. Fleet. 1977. The natural history of Nihoa Island, northwestern Hawaiian Islands. Atoll Research Bulletin 207: 1-147.
Discusses population of the threatened Pritchardia remota palm.

Clapp, R.B. and F.C. Sibley. 1971. Notes on the vascular flora and terrestrial vertebrates of Caroline Atoll, Southern Line Islands. Atoll Research Bulletin 145: 1-18.
Discusses the atoll as a coconut plantation in past years.

Clapp, R.B. and W.O. Wirtz. 1975. The natural history of Lisianski Island, northwestern Hawaiian Islands. Atoll Research Bulletin 186: 1-196.
Introduced European rabbits starved to extinction in

1915-1916 only after eating "every particle of vegetation" on Lisianski Island. A few plant species have begun to recolonize and revegetate the island.

Clark, H. 1986 (Sept. 21). Forest blaze on Big Island saddens botanists. The Sunday Star-Bulletin & Advertiser (Honolulu): A-12.
Report of an extensive fire which burned nearly 4,000 acres on the North Kona side of the Big Island, Hawaii. "This was the very best example of Hawaii dryland forest. There are nine species in that area on the endangered species list" said Quentin Tomich.

Clarke, J.F.G. 1986. Pyralidae and Microlepidoptera of the Marquesas Archipelago. Smithsonian Contributions to Zoology No. 416. 485 pp. Washington, D.C.: Smithsonian Institution.
Includes photographs depicting areas in the Marquesas where much devastation has been caused by deforestation, slashing, burning, and the introduction of horses, cattle and pigs, as well as showing pockets of original flora at higher elevations.

Clay, H.F. 1961. Narrative report of botanical field work on Kure Island, 3 October 1959 to 9 October 1959. Atoll Research Bulletin 78: 1-4.
Includes photo showing "habitat improvement", land clearance for albatross runways.

Cloud, P.E., Schmidt, R.G. and H.W. Burke. 1956. Geology of Saipan, Mariana Islands. Part 1. General Geology. U.S. Geological Survey Professional Paper 280-A. 126 pp.
"The vegetation of Saipan has been so altered by cultivation, burning, and importation of foreign species that it is difficult for any but the skilled botanist to know what plants are indigenous and which introduced."

Coblentz, B.E. 1978. The effects of feral goats (Capra hircus) on island ecosystems. Biological Conservation 13(4): 279-286.
Numerous deleterious effects of this pest are discussed.

Colinvaux, P.A., Schofield, E.K. and I.L. Wiggins. 1968. Galapagos flora: Fernandina (Narborough) caldera before recent volcanic event. Science 162: 1144-1145.
Exemplifies volcanic eruption as a natural threat to plant populations. The major, multimegaton explosion which collapsed the caldera probably killed or buried the plants on the crater walls, although summit Scalesia forest appeared almost unaffected.

Collins, M. and S. Wells. 1983. The IUCN Invertebrate RDB (Red Data Book)- Plant connections. Threatened Plants Newsletter 11: 19-21.

On Oahu (Hawaiian Islands), the indigenous Achatinella land snails are not adapting to the fast-growing introduced trees.

Colwell, R.N. 1946. The estimation of ground cover conditions from aerial photographic interpretation of vegetation types. Photogrammatic Engineering (June 1946): 151-161.
Includes photos and discussion of interconnecting facts regarding the values of plants, which are not often contemplated by altruistic botanists, e.g.: the dense concentrations of cycads in limestone areas of Okinawa indicate coral deposits at or near the surface of the earth, and such sites are ideally suited, in turn, for borrow-pit excavation of coral needed for surfacing roads and airfields.

Colwell, R.N. 1948. Aerial photographic interpretation of vegetation for military purposes. Photogrammetric Engineering (December 1948): 472-481.
The Pacific War Theatre sustained much vegetation damage in World War II. It is often on the basis of type of barrier posed to the conduct of military operations, that vegetation is classified on aerial photos for military purposes. Article includes stereogram (aerial photo) showing value of tone in differentiating coconut from betelnut palm, and discusses military value of casuarina, nipa palm, hevea rubber and cinchona. "There are four important ways in which vegetation may affect military operations: (1) it may facilitate or impede the movement of foot soldiers and motorized equipment; (2) it may accentuate or conceal evidence of military activity; (3) it may determine the ease with which clearings can be made for the construction of airfields and roads; and (4) it may serve as a source of construction material, fuel, or food."

Connell, J. 1984. Islands under pressure- population growth and urbanization in the South Pacific. Ambio 13 (5-6): 306-308, 310-312.
Discusses effects of population pressure on land.

Connell, J. 1986. Population, migration, and problems of atoll development in the South Pacific. Pacific Studies 9(2): 41-58.
Good precautionary background for considerations of development of atoll resources.

Cook, C.M. 1937. Extinction of land shell faunas of the Mangareva Islands. B.P. Bishop Museum Special Publication 30: 12-13.
Due to the destruction of practically all the native forests, the endemic land snails have been almost entirely wiped out.

Coolidge, H.J., compiler. 1948. <u>Conservation in Micronesia</u>. 70 pp. Washington, D.C.: National Research Council.
Contains 22 papers on conservation subjects by various authors, being a report on two conferences held under the auspices of the Pacific Science Board in Honolulu and Washington, D.C. in 1948.

Cooray, R.G. 1974. <u>Stand Structure of a Montane Rain Forest on Mauna Loa, Hawaii</u>. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 44. 98 pp. Honolulu, Hawaii: University of Hawaii.
Rooting activity of feral pigs destroys <u>Acacia koa</u> seedlings rooted in mineral soil. Pig populations, if allowed to increase, may cause a change in the stability trends of species populations, and an overall deterioration of this native rainforest ecosystem.

Corner, E.J.H. 1972. Urgent exploration needs: Pacific floras. <u>Pacific Science Association Information Bulletin</u> 24 (3 & 4): 17-27.
Lists operational threats in various island groups. The floras of the Admiralty Is., Santa Cruz Is., New Hebrides, Rotuma I. and Wallis I. are particularly inadequately explored.

Corporacion Nacional Forestal. 1976a. Plants, pp. 6-10, in <u>Plan de Manejo Parque Nacional Juan Fernandez</u>. Santiago, Chile: Org. Nacional Unidas para la Agric. y la Aliment., Officina Regional para America Latina.
Management plan for Juan Fernandez Is. National Park.

Corporacion Nacional Forestal. 1976b. Plants, pp. 9-10, in <u>Plan de Manejo Parque Nacional Rapa Nui</u>. Santiago, Chile: Org. Nacional Unidas para la Agric. y la Aliment., Officina Regional para America Latina.
Management plan for Rapa Nui (Easter Island) National Park.

Corwin, G., <u>et al.</u> 1957. <u>Military Geology of Pagan, Mariana Islands</u>. 259 pp. H.Q. US Army Japan.
"At present the airfield is pocked with bomb craters up to 18 feet deep and is overgrown by swordgrass, shortgrass, and scattered <u>Casuarina</u> trees."

Costa, M. 1978. The Garden of Eden alive and blooming on Kauai. <u>Latitude 20</u> (The Hawaiian Air Magazine) 6(3): 18-19, 38-39.
Article concerns the Pacific Tropical Botanic Garden, which cultivates endangered plant species.

Costin, A.B. and R.H. Groves, eds. 1973. <u>Nature Conservation in the Pacific</u>. IUCN Publications New Series, No. 25. 337 pp. Morges, Switzerland: IUCN

(International Union for Conservation of Nature and Natural Resources).

Coulter, J.W. 1931. Population and utilization of land and sea in Hawaii, 1853. B.P. Bishop Museum Bulletin 88:1-33.
Useful data for determining vegetational changes occurring since 1853.

Coulter, J.W. 1940. The relation of soil erosion to land utilization in the Territory of Hawaii. Proc. Sixth Pacific Science Congress 4: 897-901.
Soil erosion is due to perturbations of the original vegetative cover, such as pineapple cultivation and overgrazing by wild sheep and goats. Some introduced plants are good soil-binders.

Coulter, J.W. 1946. Impact of the war on South Sea islands. Geographical Review 36(3): 409-419.
Construction of many airplane fields and hangars caused forests to be "cleared and the ground leveled with broken coral. Many people profited by the "white man's war"."

Cowan, I.M. 1976. Biota Pacifica 2000, pp. 86-98, in Scagel, R.F., ed., Mankind's Future in the Pacific. 198 pp. Vancouver: University of British Columbia Press.
The discovery of the Pacific Islands by the forerunners of the Melanesians, Micronesians, and Polynesians is much more recent (in many cases as recent as within the last 1,000 years) than the history of the peopling of Africa, southern Europe and Asia. In the Pacific Islands (and the Americas and Australia), man and fauna did not evolve together as in Europe and Asia, but instead man arrived in the Pacific with a well-developed hunting technology as a totally new force upon the existing biotic equation. The author further notes that man's power of extermination was best in hitherto untouched ecosystems. The subsequent arrival of Europeans in the Pacific in the 1500's was different only in degree to the forerunners of the indigenous Pacific islanders, and included introduction of foreign grazing animals and noxious weedy plants. Mentions forest destruction; Hawaii; Laysan I.; Galapagos.

Coyne, P. 1983. Revegetation attempt on Philip Island, South Pacific. Threatened Plants Newsletter(IUCN) 12: 14.
Enclosures protecting soil from rabbit grazing give evidence of soil's ability to support growth and regeneration of native and introduced plant species.

Craine, C. 1975. Dangerous and endangered species: a

political update on native ecosystems. Newsletter Hawaiian Botanical Society 14(1): 13-18.
Mainly about the effects of axis deer and cattle on ecosystems.

Cranwell, L.M. 1984. Lehua Maka Noe, an endangered bog. Newsletter Hawaiian Botanical Society 23: 3-6.
Kauai bog appears threatened by a proposal to build an earthen dam nearby.

Creutz, E. 1966. The tiare apetahi of Raiatea. Garden Journal (New York Botanical Garden) 16(4): 142-144.
Apetahi raiateensis (Lobeliaceae) is a shrub which grows only on several acres at one locality on Temehani Plateau on the island of Raiatea, which is 100 miles northwest of Tahiti.

Cribb, P.J. 1986. The slipper orchids of New Guinea and the Solomon Islands. Kew Magazine 3(4): 159-166.
Plate 71. Paphiopedilum bougainvilleanum from Bougainville is a species endangered by over-collecting, and Plate 72. P. wentworthianum from Bougainville and Guadalcanal represents a species which numbers no more than 100-200 individuals in the wild.

Cribb, P.J., Campbell, J. and G. Dennis. 1985. Paphiopedilum in the Solomon Islands: the rediscovery of "P. dennisii". Orchid Review 93(1098): 130-131.
On Guadalcanal, much of the mountainous locale of a new Paphiopedilum orchid once provisionally named P. dennisii, and now known to be P. wentworthianum, was under shifting agriculture and then covered by secondary growth, since the plant was first discovered in 1962. In 1984 it was rediscovered in an extremely inaccessible part of the island.

Croft, K.D., Cannon, J.R., Matsuki, Y., Toia, R.F. and A.H. White. 1980. Medicinal plants of the Fiji Islands, p. 227, in Fourth Asian Symposium on Medicinal Plants and Spices. Abstracts. Bangkok: Government of Thailand and Unesco.
Work includes examination of a variety of Alyxia bracteolosa rich in alkaloids; bark alkaloids from Hernandia peltata; and coumarins from Micromelum minutum. Bleekeria vitiensis (Apocynaceae), a Fijian endemic, is believed useful in control of some cancers, and has been shown to contain a mixture of alkaloids which exhibit a wide spectrum of antitumor activity.

Croft, L., Hemmes, D.E. and J.D. Macneil. 1976. Puukohola Heiau National Historic Site plant survey. Newsletter Hawaiian Botanical Society 15(4-5): 81-94.
Site contains rare endemic pololei fern, Ophioglossum concinnum.

Crosby, W. and E.Y. Hosaka. 1955. Vegetation, pp. 28-34, in M.G. Cline, Soil Survey of the Territory of Hawaii. USDA, Soil Survey Series 1939, No. 25.
Including many interesting facts on introduced trees, including the spreading forests of algaroba (*Prosopis chilensis*), an exotic first introduced to Hawaii as a few seeds in 1820 by a French priest in Honolulu.

Cruz, F., Cruz, J. and J.E. Lawesson. 1986. *Lantana camara* L., a threat to native plants and animals. Noticias de Galapagos 43: 10-11.
The agressive introduced weed *Lantana camara* (Verbenaceae) is spreading into the breeding ground of the Hawaiian, or dark-rumped, petrel (*Pterodroma phaeopygia*) on Floreana I. in the Galapagos, forming impenetrable stands to 6 feet tall in which the birds cannot make their nesting burrows. Lantana in the area also threatens several Floreana endemic plant species, *Leucocarpus pinnatifidus* and *Scalesia villosa* (both Compositae).

Cumberland, K.B. 1949. Pacific island neighbourhood: the postwar agricultural prospect. New Zealand Geographer 5(1): 1-18.
Notes postwar vegetation changes in Fiji, Samoa, and Cook Islands.

Cumberland, K.B. 1953. Soil erosion and the world food situation. Fiji Soc. Sci. Ind. 4: 1-8.
Notes deforestation in Fiji and Rarotonga.

Cumberland, K.B. 1963. Man's role in modifying island environments in the Southwest Pacific, with special reference to New Zealand, pp. 186-206, in Fosberg, F.R., ed. (1963).
"In pre-European times, the rotation of land for food gardens and exploitation of forest resources for food, fiber, fish poisons, and ornamental coloring matter, had interfered with virtually all primary forest on islands the size of Upolu, Mangaia, Tahiti, Rarotonga and Niue, which had little, if any, truly primary forest when Europeans arrived. In New Caledonia, Viti Levu, and Vanua Levu there were large leeward and seasonally drier areas from which even secondary forest had been removed and replaced with a graminaceous cover." Also discusses effects of domestic animals and exotic weeds in the area.

Curry-Lindahl, K. 1980. Zoogeographic subregions of the Pacific realm as a background for terrestrial ecological reserves: Part 1: General introduction and northern and western Pacific regions. Environmental Conservation 7(1): 125-136; Part 2: Central and eastern regions, etc., with conclusions, op.cit. 7(2): 125-136.

Data from faunal regions and ecological zonation schemes in the islands are used to develop a scientific basis for a system of Pacific natural areas. Presents much useful animal information that can be integrated with considerations of plant species and habitats. Part 2 includes mention of plants and exotic grazing animals in Hawaiian and Juan Fernandez islands.

Curry-Lindahl, K. 1981. Twenty years of conservation in the Galapagos: Assessment, lessons and future priorities. Noticias de Galapagos 34: 8-9.
"It is vital for the future of Galapagos to acknowledge the facts that the islands are ill-adapted to human settlement, unsuitable for agriculture and that livestock has disastrous environmental effects."

Dahl, A.L. 1980. Regional Ecosystems Survey of the South Pacific Area. 99 pp. Technical Paper No. 179, South Pacific Commission and IUCN. Noumea, New Caledonia: South Pacific Commission.
Major assessment review article summarizing all available information on conservation status of South Pacific islands, including listings of rare or endemic plants, and recommended nature reserve sites.

Dahl, A.L. 1984a. Future directions for the Oceanian Realm, pp. 359-362, in McNeely, J.A. and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. 825 pp. Washington, D.C.: Smithsonian Institution Press.
"The peoples of the Pacific Islands have developed cultures and traditions with an important conservation element. However, present trends, based on external sources of food, capital, and labour, are placing much of the natural and cultural heritage of the Pacific region at risk."

Dahl, A.L. 1984b. Oceania's most pressing environmental concerns. Ambio 13(5-6): 296-301.
Includes mention of endangered species.

Dahl, A.L. 1984c. Biogeographical aspects of isolation in the Pacific. Ambio 13(5-6): 302-305.
Biota evolving in isolation result in numerous endemics and highly localized species.

Dahl, A.L. 1985. Status and conservation of South Pacific coral reefs. Proc. Fifth International Coral Reef Congress, Tahiti, 1985, 2: 95 (Abstract).
"The impacts of development in adjacent land areas and of damaging activities on the reefs themselves are probably producing a steady increase in the proportion of damaged and degraded reefs."

Dahl, A.L. and I.L. Baumgart. 1982. The state of the environment in the South Pacific, pp. 47-71, in SPREP Conference Human Environment. Report. Noumea, New Caledonia: South Pacific Commission.
Includes sections on forestry, conservation of fauna and flora, mangroves, development trends and their environmental consequences.

Danielsson, B. 1984. Under a cloud of secrecy: the French nuclear tests in the southeastern Pacific. Ambio 13(5-6): 336-341.
Perturbations of environment in Mururoa Atoll, Tuamotus.

D'Arcy, W.G. 1976. Near extinct plant in Climatron. Missouri Botanical Garden Bulletin 64(3): 5.
Lebronnecia kokioides Fosberg & Sachet (Malvaceae) reduced to one mature tree and some seedlings in the wild, from Iva-Iva in the Marquesas Islands.

Davidson, J. 1956. Peter Dillon and the discovery of sandalwood in the New Hebrides. Journal Societe Oceanistes 12(12): 99-105.
Interesting history of sandalwood forest exploitation on Eromanga from 1825 onwards. "From their heavily armed vessels, they (shipmasters) would open fire on villages whose people attempted to interfere with their despoiling of the forest." Similar incidents are recounted in Kent, G. 1972. Company of Heaven: Early Missionaries in the South Seas. 230 pp. Nashville, Tennessee: Thomas Nelson Inc.

Davis, C.J. and N.L.H. Krauss. 1961. Recent development in biological control of weed pests in Hawaii. Tenth Pacific Science Congress. Abstracts: 204-205.
New insect defoliators are effective on pernicious *Lantana camara*.

Davis, S.D., Droop, S.J.M., Gregerson, P., Henson, L., Leon, C.J., Villa-Lobos, J.L., Synge, H. and J. Zantovska. 1986. Plants in Danger: What do we know? 461 pp. Gland, Switzerland and Cambridge, England: International Union for Conservation of Nature and Natural Resources (IUCN).
A comprehensive, concise guide to information on endangered plants and their habitats around the world, and the efforts to conserve them, with detailed information for all island-groups in the Pacific Ocean.

Dawson, E.Y. 1959. Changes in Palmyra Atoll and its vegetation through the activities of man, 1913-1958. Pacific Naturalist 1(2): 1-51.
Numerous alterations to vegetation occurred concomitant with the establishment of military base.

Dawson, E.Y. 1962. Cacti of the Galapagos Islands and of coastal Ecuador. Cactus and Succulent Journal(U.S.) 34(4): 99-105.
Notes that Opuntia occurs infrequently on Charles and Chatham islands, probably due to the presence of tame and wild donkeys, and wild goats.

Dawson, J.W. 1981. The species-rich, highly endemic serpentine flora of New Caledonia. Tuatara 25(1): 1-6.
Contains endemism percentages for various localities on the island.

Decker, B.G. 1971. Plants, man and landscape in Marquesan valleys, French Polynesia. Dissertation Abstracts International 31(10): 1 page.
Contains "interpretive insights into the trend and nature of profound ecological change during almost two centuries since effective contact with European and Yankee mariners in the late eighteenth century."

Decker, B.G. 1975. Unique dry-island biota under official protection in northwestern Marquesas Islands (Isles Marquises). Biological Conservation 5(1): 66-67.
The islands are Eiao, Ile de Sable, and Hatutu. Some feral sheep and swine problems evidenced on Eiao.

Degener, O. 1945. Plants of Hawaii National Park Illustrative of Plants and Customs of the South Seas. 314 pp. Ann Arbor, Michigan.
Includes discussion of rare silversword and greensword plants (Argyroxiphium, Compositae).

Degener, O. 1963. Botanists expedition to Lanai. Newsletter Hawaiian Botanical Society 2: 107-108.
Forests of Lanai have become degraded.

Degener, O. 1966. Book review. Phytologia 13(5): 369-370.
A review of G.C. Ruhle, 1966. Waimea Canyon and Kokee, A Nature Guide. "With man's silly introduction of the passionflower (Tacsonia mollissima HBK) that smothers native trees, the raspberry (Rubus penetrans L.H. Bailey) and tibouchina (Tibouchina semidecandra Cogn.) that crowd out native shrubs and herbs, the barn owl which is a veritable flying mongoose, the goat and mouflon that browse along dry cliffs and ledges already subject to erosion without four-footed help, and the blacktailed deer that will devastate the endemic bog flora of Waialeale, man is wrecking within less than 200 years a flora that has taken 20 or so million years to perfect."

Degener, O. 1968. Comments on axis deer. Elepaio 29(3): 27.
Due to their damaging effects on vegetation, the author

refers to introduced goats, sheep, deer, mouflon, buffalo, and pigs as "four-legged vermin".

Degener, O. 1972. Axis deer damages. Elepaio 32 (11): 105-106.
Describes the annihilation of original dry forest of West Molokai by axis deer during the last 20 to 30 years.

Degener, O. 1977. Help save the dwindling endemic flora of the Hawaiian Islands at least as herbarium specimens for museums of the world. Phytologia 37(4): 281-284.
Recounts history of introduction of the pernicious weed *Clidemia hirta* (Koster's curse), and mentions that the nascent industrial forest resource base appears to favor Queensland maple, toona, and eucalypts.

Degener, O. and I. Degener. 1958. The Hawaiian beach scaevola (Goodeniaceae). Phytologia 6(6): 321.
Scaevola sericea var. *faurei* introduced to Canton Atoll in 1950-1951 has flourished.

Degener, O. and I. Degener. 1959. Canton Island, South Pacific (Resurvey of 1958). Atoll Research Bulletin 64: 1-24.
Some of the plants introduced to Canton Island have thrived and become naturalized; an update of O. Degener and E.G. Gillaspy (1955).

Degener, O. and I. Degener. 1961a. Green Hawaii: past, present and future of an island flora. Pacific Discovery 14(5): 14-17.
Evolved over a span of 13 million years, the isolated, indigenous Hawaiian flora has now become threatened by man, weeds, and grazing animals. Includes chronology of introduction of goats (in 1778), cattle and sheep (1793), horses (1803), axis deer (1867), as well as the more recently imported pronghorn antelope, mouflon sheep, brush-tailed rock wallaby, Rocky Mountain mule deer, and Columbian blacktailed deer, into Hawaii. Notes that the approximate percentage of native-growth (vegetation) remaining on each island is: Kauai-60%, Oahu-40%, Molokai-28%, Lanai-73%, Maui-34%, Hawaii-18%, and Kahoolawe-native vegetation liquidated. Includes photos of bulldozing destruction, faulty reforestation, and living type specimen of *Pritchardia macrocarpa* palm at Foster Botanical Garden.

Degener, O. and I. Degener. 1961b. A new Hawaiian variety of *Capparis*. Phytologia 7(7): 369.
"The precipitous northwest shore about Polihale, Kauai, is arid and, due to the ravages of feral goats and the competition with exotic weeds such as *Leucaena glauca* (L.) Benth. and *Pluchea odorata* (L.) Cass., almost de-

void of native plants."

Degener, O. and I. Degener. 1961c. A new Dodonaea from Molokai, Hawaii. Phytologia 7(9): 465.
Local officials are introducing continental game animals such as antelope, deer, and mouflon, and planting areas not suitable to agriculture or animal husbandry, with exotic timber trees such as pines and Samanea saman.

Degener, O. and I. Degener. 1963. Kaena Point, Oahu. Newsletter Hawaiian Botanical Society 2(6): 77-79.
The Kaena dunes area is the last stronghold of Sesbania tomentosa (Leguminosae), a vanishing species.

Degener, O. and I. Degener. 1966. Yes, thank you; we love ferns. Phytologia 13(7): 449-452.
Mentions specific areas on the islands of Hawaii, Oahu, Maui, Lanai, and Molokai, in which the native flora is in danger of extirpation.

Degener, O. and I. Degener. 1968. Review of F.E. Wimmer, Campanulaceae-Lobelioideae Supplementum. Phytologia 17(5): 369-371.
Newly describes the endangered Trematolobelia wimmeri, noting that in the area devastated by the 1959 Kilauea-Iki eruption, "in place of Trematolobelia, the unwelcome exotics Anemone japonica, Buddleja asiatica and Rubus penetrans were taking over the area."

Degener, O. and I. Degener. 1969. Review. Phytologia 19(1): 47-49.
Review of Finnish article on Hawaii, but includes information from the reviewers that "the 40 blacktail deer introduced from Canada in 1961 have multiplied steadily until there are at least 400 in the Kokee area of Kauai."

Degener, O. and I. Degener. 1970. Book review. The genus Pelea, with pertinent and impertinent remarks. Phytologia 19(5): 313-319.
Mentions collecting of the aromatic Pelea anisata for leis. Notes that the "holocaust of the native Hawaiian biota in less than two centuries is a horrible condemnation of our "civilization"."

Degener, O. and I. Degener. 1971a. Natural history of the Bonin Islands. Phytologia 21(2): 97-99.
Review of work by Japanese authors T. Tuyama and S. Asami, The Nature of the Bonin Islands, noting that overgrazed, eroded grasslands due to cattle are depicted therein.

Degener, O. and I. Degener. 1971b. Some Aleurites taxa in Hawaii and a note regarding Argemone. Phytologia 21(5):

315-319.
Aleurites moluccana var. *aulanii*, the small-seeded kukui (Euphorbiaceae) is newly described; used in seed leis. "Apparently only one tree remains in this once heavily populated valley (Waipio Valley, District of Kohala), badly mauled by careless collectors of its prized seeds."

Degener, O. and I. Degener. 1971c. *Pritchardia* and *Cocos* in the Hawaiian Islands. *Phytologia* 21(5): 320-326.
Many living colonies of loulou palm (*Pritchardia*) have succumbed to bulldozers. Notes that "Until recent bulldozing on Oahu destroyed them, erect (fossil) molds of the trunks were observable on the north side of the roadleading *mauka* to the U.S. Army Tripler General Hospital."

Degener, O. and I. Degener. 1971d. Review and comments about a thing. *Phytologia* 21(6): 369-374.
Review of R.E. Warner, ed., *Scientific Report of the Kipahula Valley Expedition*, sponsored by The Nature Conservancy. Notes that "When *Astelia* species are terrestrial, feral pigs feed on the rhizomes and young leaves, often destroying the colonies. They also penetrate the higher stretches of cinder-covered terrain where the endemic bracken can survive with its underground rhizomes to the exclusion of other vascular plants. Pigs, with great ease, root out the rhizomes from the friable ash, pumice and cinders for food."

Degener, O. and I. Degener. 1971e. *Sophora* in Hawaii. *Phytologia* 21(6): 411-415.
"Today, with Lanai practically a hunting preserve stocked with feral goat, axis deer, mouflon and pronghorn, we surmise the four trees (of *Sophora lanaiensis*) are no more...We believe this species (*Sophora molokaiensis*) extinct because, when we collected specimens of the plant in 1961 the area, thanks to the jeep road, was being bulldozed in strips for the planting of *Pinus taeda* to foster a lumber industry."

Degener, O. and I. Degener. 1972. *Wikstroemia pulcherrima* var. *petersonii* Deg. & Deg., from Hawaii. *Phytologia* 24(2): 151-154.
This variety is being exterminated by trampling cattle except between roadside fences.

Degener, O. and I. Degener. 1973. *Santalum paniculatum* var. *chartaceum* Deg. & Deg. *Phytologia* 27(3): 145-147.
"As many owners of this subdivision (Fern Forest Estates, Puna, Hawaii) are having their lots bulldozed clean of the endemic forest to replant them with *Psidium guajava* L. for an anticipated jam, jelly and juice

industry, this interesting taxon may not survive many more years."

Degener, O. and I. Degener. 1974a. Appraisal of Hawaiian taxonomy. Phytologia 29(3): 240-246.
Contains a capsule-commentary on history of human intervention in Hawaiian endemic flora and vegetation.

Degener, O. and I. Degener. 1974b. Flotsam and jetsam of Canton Atoll, South Pacific. Phytologia 28(4): 405-418.
Includes map indicating areas disturbed by bulldozing operations on Canton Island.

Degener, O. and I. Degener. 1974c. To save a rare naupaka. Newsletter Hawaiian Botanical Society 13(4): 16.
On sand dunes next to golf course at Waihee, 300 individuals of Scaevola coriacea are still surviving.

Degener, O. and I. Degener. 1975a. Silverswords and the Blue Data Book. Notes Waimea Arboretum 2(1): 3-6.
Historical causes of endangerment of the Hawaiian flora, particularly the decline of Argyroxiphium (Compositae).

Degener, O. and I. Degener. 1975b. Concerning a magazine article. Degener's Leaflet No. 3. 6 pp.
Notice of miscaptioned Hawaiian Argyroxiphium in D.W. Jenkins and E.S. Ayensu (1975).

Degener, O. and I. Degener. 1976. Wikstroemia perdita Deg. & Deg., an extinct(?) endemic of a paradise lost by exotic primates. Phytologia 34(1): 28-32.
A thymelaeaceous species known only from one male tree occurring in a bulldozed Hawaiian Metrosideros forest propels the authors into a swirling continuum of invective directed at "idiotic Primapes", namely the exotic primates (humankind) of the article's title.

Degener, O. and I. Degener. 1977a. Book review. Phytologia 35(3): 220.
Review of M.D. Merlin, 1976.Hawaiian Forest Plants. "Its lasting value is conservational, helping to stem the tide of extermination of Hawaii's botanical treasures."

Degener, O. and I. Degener. 1977b. Hibiscadelphus number KK-HX-1: an international treasure in Hawaii. Phytologia 35(5): 385-396.
Concerns a plant of H. giffardianus which is a direct descendant of the type specimen tree. Lists many introduced exotics becoming weedy in Hawaii Volcanoes National Park.

Degener, O. and I. Degener. 1977c. Some taxa of red-flowered hibiscus endemic to the Hawaiian Islands. Phytologia 35(6): 459-470.

The Hawaiian Hibiscus Society's living collection in Waikiki, Honolulu contained about 20 endemic Hawaiian species. The plantings were suddenly bulldozed without much prior warning, and the area was summarily converted into a scientifically worthless rose garden.

Degener, O. and I. Degener. 1984. To whom it may concern: regarding Kahauale'a Geothermal Project. Notes Waimea Arboretum 11(2): 6-12.
A plea to confine the proposed project, located on the island of Hawaii, to lower elevations where vegetation has already been massacred, rather than to the high elevations where indigenous flora still survives.

Degener, O., Degener, I. and H. Hormann. 1969. Cyanea carlsonii Rock and the unnatural distribution of Sphagnum palustre L. Phytologia 19(1): 1-3.
Cyanea carlsonii on island of Hawaii is threatened by possibility of grazing animals and is evidently nearly extinct. Sphagnum moss formerly was harvested above Waipio to be "used for enbaling earth-free seedlings of exotic timber trees before carrying them into the jungle for planting."

Degener, O. and E. Gillaspy. 1955. Canton Island, South Pacific. Atoll Research Bulletin 41: 1-51.
During World War II, there was extensive construction and land-grading on Canton. Article lists ornamental and useful plant seeds later supplied from Hawaii in an attempt to revegetate the bare island with a binding plant cover for induction of land stabilization.

Degeners and Sunadas. 1976. Argyroxiphium kauense, the Kau silversword. Phytologia 33(3): 173-177.
Notes that the plant is "very localized in distribution and exposed to extinction in case a flow of lava should overwhelm the area from the summit of actively volcanic Mauna Loa, or from introduced insects and browsing animals or exotic weeds."

DeGroot, R.S. 1983. Tourism and conservation in the Galapagos Islands. Biological Conservation 26(4): 291-300.
Consideration of tourist impact and how to contain it.

Dening, G. 1982. The Marquesas. 111 pp. Papeete, Tahiti: Les Editions du Pacifique.
Includes photo of Motane I. in which feral sheep appear.

DeRoy, T. 1987. When aliens take over. International Wildlife 17(1): 34-37.
Discusses the effects of feral animal invaders in the Galapagos, including the cows on Isabela I. which trample ferns and brush and thereby promote the spread of

grasslands, and the goats which transform dry areas into deserts.

D'Espeissis, J.L. 1953. Forestry in Fiji. Trans. & Proc. Fiji Society of Science and Industry 3(2): 130-139.
Fijian soil erosion and soil fertility losses are caused by unwise land use, uncontrolled burning, and timber cutting.

Devaney, D.M., Kelly, M., Lee, P.J. and L.S. Motteler. 1976. Kaneohe: A History of Change (1778-1950). 271 pp. Honolulu, Hawaii: Bernice P. Bishop Museum.
Notes that eleven species of threatened and vulnerable Cyrtandra are located in the Kaneohe Bay region of Oahu (Hawaiian Islands): 6 species from Waikane, 3 from Waiahole, and 1 each from Heeia and Kaneohe.

DeVries, T. 1977. Como la caza de chivos afecta la vegetacion en las Islas Santa Fe y Pinta, Galapagos. Rev. Universidad Catolica 5(16): 171-181.
Discusses hunting of goats on two of the Galapagos Islands, Santa Fe and Pinta, and its effect on vegetation recovery.

DeVries, T. and J. Black. 1983. Of men, goats and guava: problems caused by introduced species in the Galapagos. Noticias de Galapagos 38: 18-21.
"The most serious threats to the native vegetation by introduced plants are those caused by guava, cinchona, various grasses and, on some islands, Lantana camara.

Diamond, J.M.(convener). 1982. Implications of island biogeography for ecosystem conservation, pp. 46-60, in Siegfried, W.R. and B.R. Davies, eds., Conservation of Ecosystems: Theory and Practice. 97 pp. South African National Science Programmes Report No. 61. Pretoria: CSIR.
An introduction to current theoretical and practical considerations of biotic extinctions on islands, including such concepts as differential extinction risk; r-strategy and K-strategy types of life-history effects; and the "trophic cascade" effect mode of sequential extinction in relation to reintroduction into the wild.

DiCastri, F. and G. Glaser. 1980. Highlands and islands: ecosystems in danger. The Unesco Courier(April 1980): 6-11.
Land in eastern Fiji must be used for subsistence agriculture, rather than for other purposes.

DiSalvatore, B. 1981. The goat men of Aguijan. Islands 1(1): 86-92.
Aguijan I. (Marianas) is uninhabited by humans, but

supports c. 1,500 feral goats and is occasionally visited by goat hunters. In the early 1940's the Japanese introduced Australian pine as windbreaks, and massive pineapple and sugarcane plantations. Goats had exterminated much original vegetation in their wanderings.

Doan, D.B., _et al._ 1960. _Military Geology of Tinian, Mariana Islands._ 149 pp. H.Q. US Army Pacific.
"Land so severely altered by construction or preparation of military installations as to be beyond reasonable possibility of rehabilitation for agriculture or restoration to any semblance of its natural state has been mapped and measured."

Doan, D.B., Paseur, J.E. and F.R. Fosberg. 1960. _Military Geology of the Miyako Archipelago, Ryukyu-Retto._ 214 pp. H.Q. US Army Pacific.
"In almost every area, any part of the vegetation that is of any use to man has been, and is still being, exploited mercilessly, leaving scarcely a stick of firewood worth carrying home."

Dodd, E. 1976. _Polynesia's Sacred Isle._ 224 pp. New York: Dodd, Mead & Company.
Volume III of _The Ring of Fire_ trilogy, this book contains much valuable data on the "tiare apetahi", _Apetahia raiateensis_, a lobelioid endemic to Mt. Temehani on Raiatea, Society Islands.

Dodge, E.S. 1976. _Islands and Empires: Western Impact on the Pacific and East Asia._ 350 pp. Minneapolis: University of Minnesota Press.
"The first impact of sandalwooding was felt from about 1790 to 1820 in the Polynesian islands and Fiji...Marquesan wood was cleaned out in only three years, beginning in 1814, but sandalwooding in Hawaii and Fiji spanned a decade or two and had a profound effect on the people of those islands."

Doe, G.T. 1971. The battle of Kwajalein. _Micronesian Reporter_ 19(1): 17-25.
Includes photos of vegetation devastation resulting from 1944 battle in the Marshall Islands.

Donaghho, W.R. 1970. Destruction of virgin ohia and koa forest on Hawaii by the Division of Forestry. _Elepaio_ 30(7): 67.
"The present program of forest destruction on Hawaii must stop. No one has the right to ruin our natural resources in this manner."

Doran, E. 1959. _Handbook of Selected Pacific Islands._ 223 pp. Pacific Missile Range, Point Mugu, California.

Publication No. PMR-MP-59-30.
"In general, the northern half of Eniwetok Atoll, subjected to AEC tests, does not have a "normal" vegetation. Site Irene, for example, is devoid of all vegetation. Heavy fighting in World War II destroyed most of the trees on the larger islets and, indeed, not one tree survived into 1946 on Fred (Eniwetok)."

Doria, J.J. 1979. Haleakala's silversword has a chance. National Parks and Conservation Magazine 53(12): 14-16.
Argyroxiphium macrocephalum, once on the verge of extinction, is protected in Haleakala National Park, Hawaii, but feral goats are serious obstacles to recovery.

Dorst, J., et al. 1972. Conservation, pp. 69-74, in Simkin, T., et al., eds., Galapagos Science: 1972 Status and Needs. Washington, D.C.: Smithsonian Institution.
A call for baseline and control studies of introduced destructive plants and animals, and for population dynamics and monitoring studies of endangered plant species.

Doty, M.S. 1969. The Ecology of Honaunau Bay, Hawaii. 221 pp. Hawaii Botanical Science Paper No. 14. University of Hawaii.
The vegetation at Honaunau has become so weedy that the author concludes there is no compelling botanical reason to bother about preserving it in its present condition.

Doty, M.S. 1973. Chapter 16. Marine organisms, tropical algal ecology and conservation, pp. 183-196, in A.B. Costin and R.H. Groves, eds. (1973).
For the study of invasive species, population dynamics and equilibrium, and algal phytogeography, the algal ecosystems of the Pacific Islands are worthy of conservation as a prelude to planned rational use of their resources.

Douglas, B. 1971. The export trade in tropical products in New Caledonia, 1841-1872. Journal Societe Oceanistes 31: 157-169.
Includes consideration of the sandalwood export trade.

Douglas, G. 1970. Draft check list of Pacific oceanic islands. Micronesica 5(2): 327-463.
Remarks on land use history and conservation status of various islands are included.

Doumenge, F. 1963. L'ile de Makatea et ses problemes. Cahiers du Pacifique 5: 41-68.
Impacts of intensive phosphate exploitation are discussed.

Dousset, R. and E. Taillemite. Undated(post-1978). The Great Book of the Pacific. 279 pp. Dee Why West, Australia: Books for Pleasure.
Sumptuous account of Pacific island cultures, including much on human immigration and development in New Caledonia. There, "the silvery niaouli bush, which produces soothing oil and provides so many cures with its bark, disappears into paper factories, while the nickel works spew their red dust into the air to darken the once crystal clear waters of the rivers...Meanwhile modern medicine is there to cure diseases which were formerly contained by a better adaptation to natural life". (Cf. Prior, I. and J. Stanhope, 1980).

Drahos, N. 1974. New specimen of Guam's rarest tree found. Guam Rail 8(9): 5.
An account of the discovery of the second known living specimen of Serianthes nelsonii (Leguminosae), which was found in 1974 on Pati Point, Andersen Air Force Base, Guam.

Duefrene, P. 1984. The top of Mauna Kea. Aloha 7(4): 62-67.
Discusses the effects of overgrazing cattle, sheep, and goats on the mamane-naio forests, as well as consequences for endangered birds. Mauna Kea is on the Big Island of Hawaii.

Duffy, D.C. 1981. Ferals that failed. Noticias de Galapagos 33: 21-22.
It is refreshing to consider the failure and partial failure of animals which are destructive to vegetation and are, or were, introduced in the Galapagos. Goats failed in only a few places, but feral sheep, deer and rabbits are fortunately exterminated in the islands.

Dugain, F. 1953. Degradation et protection des sols de la Nouvelle-Caledonie. Et. Melan. n.s. 5(7): 69-86.
A cause of soil degradation in New Caledonia is erosion induced by destruction of vegetation.

Dutton, C.E. 1884. Hawaiian volcanoes. U.S. Geological Survey Annual Report 4: 75-219.
Useful for comparison of vegetation status between 1882 and the present time.

Dworsky, S. 1986. Two in the tropics.Horticulture 64(3): 56-62.
The Pacific Tropical Botanical Garden and Allerton Gardens on Kauai (Hawaiian Islands) preserve plant species threatened with extinction in their natural habitat.

Dybas, H.S. 1948. Comments on conservation in Micronesia,

pp. 58-59, in H.J. Coolidge, compiler (1948).
Indicates the least-damaged vegetated areas, as well as general threats, in the Marianas (Tinian, Saipan, Guam) and Carolines (Palau, Ponape).

E., M. 1938. One hundred and fiftieth anniversary of the "Bounty" expedition. Gardeners' Chronicle ser.3, 104: 305-306.
Cutting of trees on Pitcairn Island affected rainfall and soil fertility.

Eckhardt, R.C. 1972. Introduced plants and animals in the Galapagos Islands. BioScience 22(10): 585-590.
Discusses the disastrous effects of many species.

Egler, F.E. 1939. Vegetation zones of Oahu, Hawaii. Empire Forestry Journal 18(1): 44-57.
Includes details of vegetation zones dominated by foreign, fast-spreading plants including guava, and other significant aliens such as Coffea arabica (Kona coffee). The introduced guava zone of vegetation is being invaded by Psidium guajava and Psidium cattleianum var. lucidum, which are themselves guavas.

Egler, F.E. 1941. Unrecognized arid Hawaiian soil erosion. Science 94: 513-514.
Concerns the relationship between vegetation and soil erosion.

Egler, F.E. 1942. Indigene versus alien in the development of arid Hawaiian vegetation. Ecology 23(1): 14-23.
On Oahu, in the absence of anthropic influences, most of the alien plants will be destroyed by the indigenous plants.

Egler, F.E. 1947. Arid southeast Oahu vegetation, Hawaii. Ecological Monographs 17(4): 383-435.
Includes section on grazing factors which inhibit and destroy original vegetation.

Egler, F.E. 1956. Oceania, pp. 611-630, in A World Geography of Forest Resources. The Ronald Press Company.
Includes discussion of the deleterious effects of man in the Pacific forests, subdivided into "Black Men and Brown Men" (Melanesians, Micronesians and Polynesians) and "White Men and Yellow Men" (the equally destructive Europeans and Mongoloid people arriving later).

Eibl-Eibesfeldt, I. 1960. Naturschutzprobleme auf den Galapagos-Inseln. Acta Tropica 17(2): 97-137.
Includes a brief mention, with photo, of the decimating effects of wild goats on Barrington Island (Galapagos), where they consumed all the vegetation except columnar cactus.

Eliasson, U. 1968. On the influence of introduced animals on the natural vegetation of the Galapagos Islands. Noticias de Galapagos 11: 19-21.
Endemic Scalesia, Calandrinia and Portulaca species are detrimentally affected by feral grazing animals.

Eliasson, U. 1982. Changes and constancy in the vegetation of the Galapagos Islands. Noticias de Galapagos 36: 7-12.
Threatening introduced plants affecting natural vegetation include Cinchona succirubra on Santa Cruz I. and Kalanchoe pinnata on Floreana.

Elliott, H.F.I. 1973. Chapter 20. Past, present and future conservation status of Pacific islands, pp. 217-227, in A.B. Costin and R.H. Groves, eds.(1973).
Presents data on frequency of the following types of disturbances known to adversely affect Pacific island ecosystems: 1. airstrips, airports; 2. coconut planting; 3. tourism, private ownership; 4. fowling; 5. mining, salt, phosphates; 6. military, naval, air bases; 7. nuclear and other weapons testing; 8. penal, leper, quarantine stations; 9. cattle and sheep; 10. horses and donkeys; 11. pigs; 12. cats, dogs, foxes; 13. poultry; 14. goats; 15. rabbits; 16. mice; 17. rats.

Elliott, M.E. and E.M. Hall. 1977. Wetlands and Wetland Vegetation of Hawaii. 344 pp. Report prepared for the U.S. Army Corps of Engineers, Pacific Ocean Division, Fort Shafter.
Detrimental disturbance factors, when present, are noted for 62 wetland sites. Destructive management practices are often applied to Hawaiian wetlands.

Ellis, W.S. 1986. Bikini: a way of life lost. National Geographic 169(6): 813-834.
Intriguing story of the post-war nuclear test blasts on Enewetak and Bikini atolls (Marshall Is.), and subsequent radioactive contamination clean-up attempts.

Ellshoff, Z.E.1986. Symposium on control of introduced plants in native ecosystems of Hawaii: summary of presentations. Newsletter Hawaiian Botanical Society 25(3): 79-88.
Contains a summary of the important facts gleaned from the presented papers, along with he Program of the symposium, which occurred on June 10-12, 1986.

Elton, C.S. 1958. The Ecology of Invasions by Animals and Plants. 181 pp. London: Methuen.
Includes comments on vegetation impacted on Easter Island and Hawaiian Islands.

Ely, C.A. and R.B. Clapp. 1973. The natural history of Laysan Island, northwestern Hawaiian Islands. Atoll Re-

search Bulletin 171: 1-361.
"Rabbits introduced in 1903...and only the timely arrival of the Tanager expedition in 1923 saved the island from complete devegetation."

Evans, E.C., Murchison, A.E., Peeling, T.J., and Q.D. Stephen-Hassard. 1972. A Proximate Biological Survey of Pearl Harbor, Oahu. 65 pp. NUC-TP 290. San Diego, California: Naval Undersea Research and Development Center.
Includes list of 10 endangered plant species of the area, which are co-existing with introduced European weeds.

Eyde, R.H. and S.L. Olson. 1983. The dead trees of Ilha da Trindade. Bartonia 49: 32-51.
Studies by Professor D. Mueller-Dombois on dieback of Metrosideros collina forests on island of Hawaii are referred to in this study of disappearing trees on an Atlantic Ocean island.

Fagerlund, G.O. 1947. The Exotic Plants of Hawaii National Park. 62 pp., mimeod. Hawaii National Park, Natural History Bulletin, No. 10.
Where the vegetation of an area remains in its original condition, foreign plants have little chance to establish themselves. But much of the Kilauea-Mauna Loa section of Hawaii National Park (244 square miles) has been disturbed and exotic plants have invaded. Birds, especially alien species, are distributing agents for seeds of many alien plants. Includes checklist of 384 exotic species in the park. Report notes the peculiar fact that many of these plants were introduced in order to add variety to the perceived visual "monotony" possessed by the indigenous Hawaiian vegetation. A long bibliography is provided.

Falanruw, M.V.C. 1971. Conservation in Micronesia. Atoll Research Bulletin 148: 18-20.
Originally, man's culture included the practice of limitation of human population; this practice formed a buffer which prevented the destruction of his islands. Other original preservation factors include self-imposed "conservation laws", complex land ownership systems, and various taboos.

Falanruw, M.C. 1976a. Life on Guam: Human Impact. 84 pp. Guam Department of Education.
Workbook on Guam ecological and environmental problems for high schools. Notes that almost two-thirds of Guamanian plant species are introductions from elsewhere.

Falanruw, M.C. 1976b. Life on Guam: Savanna, Old Fields,

Roadsides. 74 pp. Guam Department of Education.
Workbook for high schools, including topics such as savanna burning effects, soil erosion caused by motorcycle tracks, reforestation programs, and the parade of invasive American pests including tangan-tangan (Leucaena leucocephala).

Falanruw, M.V.C. 1985. People pressure and management of limited resources on Yap, pp. 348-354, in McNeely, J.A. and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Washington, D.C.: Smithsonian Institution Press.
"Prospects for sustainable development seem dismal."

Faulkner, D. 1981. Palau: a pattern of islands. Oceans 14(4): 36-43.
Management plan threatens island.

Fay, J.J. 1978. Hawaii: extinction unmerciful. Garden 2(4): 22-27.
Elaborates the reasons for, and extent of, plant decimation in the Hawaiian Islands.

Fay, J.J. 1980 (2 September). Endangered and threatened wildlife and plants: proposed endangered status for the 'Ewa Plains 'akoko (Euphorbia skottsbergii var. kalaeloana). Federal Register 45(171): 58166-58168.
This, and the Fay citation following it, are included to demonstrate the process whereby a plant species is officially listed as endangered or threatened pursuant to the U.S. Endangered Species Act of 1973, by means of a notice proposing its status; then a waiting period during which further status information is collected from interested individuals in the scientific, commercial, and public communities; and then the publication of a final rulemaking or determination. All are published under auspices of the U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C., in the Federal Register.

Fay, J.J. 1982 (24 August). Endangered and threatened wildlife and plants: determination that Euphorbia skottsbergii var. kalaeloana ('Ewa Plains 'Akoko) is an endangered species. Federal Register 47(164): 36846-36849.
See annotation under preceding citation.

Fernald, E.F. 1981. A decision-making process for application to island resources, pp. 59-68, in Force, R.W. and B. Bishop, eds., Persistence and Change. 155 pp. Honolulu, Hawaii: Pacific Science Association.
Suggests that information on a particular island's potentially and actually destructive alien plants and grazing animals should be included as resource manage-

ment data, since those organisms represent the possibility of causing local ecosystem instability.

Fischer, J.L. and A.M. Fischer. 1957. The Eastern Carolines. 274 pp. Washington, D.C.: Pacific Science Board.
Includes general remarks on condition of natural vegetation on the islands, noting, e.g., that nearly all mature native Exorrhiza palm trees on Truk were chopped down by the Japanese during World War II in order to consume the terminal bud as a green vegetable called "heart of palm".

Fisher, H.I. 1949. Populations of birds on Midway and the man-made factors affecting them. Pacific Science 3(2): 103-110.
Includes effects of war activities on the vegetation.

Fisher, H.I. 1966. Airplane-albatross collisions on Midway Atoll. Condor 68: 229-242.
Depicts bulldozed vegetation on Midway.

Flanders, G. 1985. Preserving Hawaii's heritage. Hawaii 2(3): 22-25.
Short but excellent article discussing panoply of threats to Hawaii's botanical heritage. Cattle destroy more of Hawaii's native plants than any other animal, yet the State of Hawaii leases out 200,500 acres for cattle grazing. Also reports that in one leasing situation, government-owned koa trees, which provided a habitat for the severely endangered alala bird, were felled for sale despite the repeated objections of state foresters. 10 photos.

Forbes, C.N. 1911. Notes on the naturalized flora of the Hawaiian Islands. Occasional Papers, B.P. Bishop Museum 4(5): 23-34.
"Introduced weeds appear along new trails through the native forest in from two to three weeks in places where it would be impossible to find them before."

Forbes,C.N. 1913a.Notes on the flora of Kahoolawe and Molokini. Occasional Papers, B.P. Bishop Museum 5(3): 3-15.
On Kahoolawe (Hawaiian Is.), "goats cause considerable harm by girdling the keawe (Prosopis juliflora), a tree introduced here about fifteen years ago and spread by horses and mules."

Forbes, C.N. 1913b. An enumeration of Niihau plants. Occasional Papers, B.P. Bishop Museum 5(3): 17-29.
Although this Hawaiian island was formerly overrun with goats, most of its available land is now used as sheep and horse pasture.

Force, R.W. 1981. Introduction: Change, nonchange, and exchange, pp. 1-13, in Force, R.W. and B. Bishop, eds., Persistence and Change. 155 pp. Honolulu, Hawaii: Pacific Science Association.
Includes mention of the consequences of plantdisturbance to Palau and Hawaii in this review of man's arrival and subsequent utilization of natural resources in the Pacific.

Fosberg, F.R. 1936. Plant collecting on Lanai, 1935. Mid-Pacific Magazine 49: 119-123.
Discusses rehabilitation of Lanai vegetation.

Fosberg, F.R. 1937a. An aggressive Lantana mutation. B.P. Bishop Museum Special Publication 31: 18.
An aggressive form of Lantana camara has spread to large areas in Manoa and Palolo valleys, Oahu. The Oahu mutation has corolla white, with yellow tube, and more prickly stems than the typical form. It is replacing the normal form rapidly, due to greater shade tolerance, greater seed production, and greater resistance to parasites.

Fosberg, F.R. 1937b. Immigrant plants in the Hawaiian Islands. I. University of Hawaii Occasional Papers No. 32: 3-11.
Includes objectionable Compositae: Pluchea, Eupatorium, and Elephantopus.

Fosberg, F.R. 1942. Uses of Hawaiian ferns. American Fern Journal 32(1): 15-23.
It is likely that wild hogs and other introduced animals are responsible for the destruction of the "pala" (Marattia douglasii), which was formerly rather common in Hawaii, and is today rare.

Fosberg, F.R. 1948a. Immigrant plants in the Hawaiian Islands. II. University of Hawaii Occasional Papers No. 46: 1-17.
An early warning of many exotics which have since become pernicious smotherers of the indigenous vegetation.

Fosberg, F.R. 1948b. Island floras, pp. 18-21, in H.J. Coolidge, compiler (1948).
Discusses the peculiarities and vulnerability of island floras in the Carolines and Marianas, and the need to conserve irreplaceable plants.

Fosberg, F.R. 1948c. Derivation of the flora of the Hawaiian Islands, pp. 107-119, in Zimmerman, E.C., Insects of Hawaii, vol. 1. Introduction. Honolulu, Hawaii: University of Hawaii Press. (Reprinted as pp. 396-408 in Kay, E.A., ed., 1972. A Natural History of the Hawaiian Islands- Selected Readings . Honolulu, Hawaii:

University of Hawaii Press.)
"An average of one successful arrival and establishment every 20,000 to 30,000 years would account for the flora..., granting an estimate of 5 to 10 million years of above-water history for the entire Hawaiian chain."

Fosberg, F.R. 1949. Flora of Johnston Island, Central Pacific. Pacific Science 3(4): 338-339.
By 1946, "there was apparently no original vegetation remaining, the whole island being occupied by runways and buildings with disturbed ground in the open places and along paths and roadsides."

Fosberg, F.R. 1950. The problem of rare and vanishing plant species. Proc. Papers International Technical Conference, Protection of Nature, Lake Success 1949: 502-504.
Many Pacific plants have nearly vanished, e.g. *Capparis carolinensis* from island of Peleliu represented by one living specimen in 1946, and causes of such diminishment are generally goats, temporary agriculture, and weedy exotic plants crowding out the indigenous flora.

Fosberg, F.R. 1951. Micronesia, pp. 515-517, in IUCN, The Position of Nature Protection Throughout the World in 1950. Brussels: IUCN.
"Old habits, such as that of burning the vegetation, are destructive...the natives do not understand why they should not burn grass, brush, and forest."

Fosberg, F.R. 1953a. A conservation program for Micronesia. Proc. Seventh Pacific Science Congress 4: 670-673.
Discussion of atoll and high island conservation problems.

Fosberg, F.R. 1953b. The naturalized flora of Micronesia and World War II. Eighth Pacific Science Congress Abstracts, pp. 174-176.
Introduction and spread of plant species as a result of the war.

Fosberg, F.R. 1953c. Vegetation of Central Pacific atolls: a brief summary. Atoll Research Bulletin 23: 1-26.
Includes comments on changes caused by activities of man.

Fosberg, F.R. 1954a. Vanishing island floras and vegetation. IUCN Technical Meeting, Caracas, 1952 (Reports), pp. 538-543.
Protection of lowland flora, which often contains interesting species (not just widespread plants as so often assumed), is encouraged, especially for Hawaiian Is., Palau, Fiji, and the Solomons.

Fosberg, F.R. 1954b. The protection of nature in the islands of the Pacific. VIII Congres International de Botanique, pp. 104-116.
With the advent of the Europeans, several events occurred which ultimately resulted in widespread disaster for nature in the Pacific: (1) the release of goats and other hoofed animals, (2) the introduction of steel tools, and (3) the introduction of a commercial economy as against the originally developed subsistence agriculture. To these events were later added the effects of World War II and considerations of human population increases.

Fosberg, F.R. 1955. Northern Marshall Islands Expedition, 1951-1952. Narrative. Atoll Research Bulletin 38: 1-36.
Includes notes on adventive, weedy vegetation which rapidly colonized such islands as Wake after World War II.

Fosberg, F.R. 1956a. The protection of nature in the islands of the Pacific. 8me Congres International de Botanique C.R. Seances 21-27: 104-117.
Progress in conservation on Micronesia, particularly Guam, is reported.

Fosberg, F.R. 1956b. Vegetation, pp. 185-220, in Military Geography of the Northern Marshalls. 320 pp. H.Q. US Army Forces Far East.
Discussion of 21 atolls includes revegetation of areas denuded either naturally or by military operations, and rates of change in plant communities, often smothered by weeds.

Fosberg, F.R. 1957a. Vegetation of the Oceanic Province of the Pacific. Proc. Eighth Pacific Science Congress 4: 48-55.
Includes numerous general and specific observations on vegetation alteration and disruption in the Pacific islands.

Fosberg, F.R. 1957b. The naturalized flora of Micronesia and World War II. Proc. Eighth Pacific Science Congress 4: 229-234.
During the war, Angaur and Peleliu were almost completely burned over; scarcely an acre of Saipan remained undisturbed; and the northern plateau of Guam was heavily impacted. These and other areas afforded habitats for new invasions of weeds after the cessation of hostilities.

Fosberg, F.R. 1959a. Long-term effects of radioactive fallout on plants? Atoll Research Bulletin 61: 1-11. Condensed in Nature 183: 1448 (1959).
Islets in Utirik, Ailinginae, Rongelap, and Rongerik

atolls display a vegetation in very poor condition with visible abnormalities, after the Castle Bravo bomb test on Bikini Atoll on March 1, 1954.

Fosberg, F.R. 1959b. Vegetation and flora of Wake Island. Atoll Research Bulletin 67: 1-20.
Includes discussion of regeneration of the Wake vegetation after three years of almost daily bombardment in World War II.

Fosberg, F.R. 1959c. Conservation situation in Oceania. Proc. Ninth Pacific Science Congress 7: 30-31.
In the past 4 years, 5 conservation areas were set aside in Guam to preserve examples of forest; mouflon, or wild sheep, were introduced on Lanai and Kauai (Hawaiian Is.); the French administration in New Caledonia decided to go ahead with construction of a dam which would flood the famous Plaine des Lacs, with its remarkable aggregation of rare and endemic plants; Christmas Island was used for nuclear weapons testing; colonization and sheep ranching were encouraged on Juan Fernandez Islands National Park (Chile); and, goats were introduced into Henderson Island.

Fosberg, F.R. 1959d. Vegetation, pp. 168-172, in Tracey, J.I., et al. (1959).
On Guam, "A long history of disturbance by the Guamanians, by frequent typhoons, and by the destructive effects of World War II and subsequent military activities, has left little undisturbed primary forest on the island."

Fosberg, F.R. 1960a. The vegetation of Micronesia: 1. General descriptions, the vegetation of the Marianas Islands, and a detailed consideration of the vegetation of Guam. Bulletin American Museum of Natural History 119, Article 1: 75 pp. + 40 plates.
Abundant information on disturbance, secondary forests, succession, deterioration of vegetation through effects of introduced plants, wartime activities, land clearance, and intensive pre-World War II phosphate mining.

Fosberg, F.R. 1960b. Vegetation, pp. 165-187, in Doan, D.B., et al., Military Geology of the Miyako Archipelago, Ryukyu-Retto. H.Q. US Army Pacific.
"The vegetation of even the completely uncultivable areas of limestone with practically no soil has been profoundly influenced by man."

Fosberg, F.R. 1960c. Vegetation, pp. 51-84, in Foster, H.L., et al., Military Geology of Ishigaki-Shima, Ryukyu-Retto. H.Q. US Army Pacific.
The vegetational aspect of this island is changing due to introduction of exotic plants, and active land

clearing for pineapple plantations has greatly reduced the amount of forest at base of mountains.

Fosberg, F.R. 1961. Typhoon effects on individual species of plants, pp. 57-68, in Blumenstock, D.I., ed., A report on typhoon effects upon Jaluit Atoll. Atoll Research Bulletin 75: 1-105.
Devastating impact of Typhoon Ophelia on January 7, 1958.

Fosberg, F.R. 1963a. Grazing animals and the vegetation of oceanic islands, pp. 168-169, in Unesco, Symposium on the Impact of Man on Humid Tropics Vegetation (Goroka, Papua New Guinea). 402 pp. Djakarta.
Consideration of vegetation disturbance by grazing quadrupeds.

Fosberg, F.R. 1963b. Disturbance in island ecosystems, pp. 557-561, in Gressitt, J.L., ed. (1963).
Mentions Hawaiian examples of ecosystems extremely susceptible to disturbance.

Fosberg, F.R., ed. 1963 (Reprinted 1965). Man's Place in the Island Ecosystem: A Symposium. 264 pp. Honolulu: Bishop Museum Press.

Fosberg, F.R. 1966. The volcanic island ecosystem, pp. 55-61, in Bowman, R.I., ed., The Galapagos. Berkeley and Los Angeles: University of California Press.
Includes brief discussion on status of Galapagos Islands ecosystems.

Fosberg, F.R. 1967. Some ecological effects of wild and semi-wild exotic species of vascular plants, pp. 98-109, in Towards A New Relationship of Man and Nature in Temperate Lands, Part III. Changes due to Introduced Species. IUCN Publications New Series, No. 9. Morges, Switzerland: IUCN.
Review article includes mention of invasion of *Eupatorium adenophorum* on Molokai, Hawaiian Is.

Fosberg, F.R. 1968a. Some relations between ecosystem size and cultural evolution, pp. 702-704, in Misra, R. and B. Gopal, eds., Proceedings of the Symposium on Recent Advances in Tropical Ecology, Part II. Varanasi, India: International Society for Tropical Ecology.
Resistance of traditional cultures to introduced cultures in the Pacific has tended to break down, and the ecological effects of such deterioration include accelerated soil erosion, siltation of marine environments, and abandonment of taro culture and the highly evolved irrigation systems that accompany it.

Fosberg, F.R. 1968b. Systematic notes on Micronesian

plants. Phytologia 15(7): 496-502.
Mimosa invisa from Saipan and Palau, an "unpleasant, viciously spiny Brazilian creeper,...should be ruthlessly eradicated wherever found."

Fosberg, F.R. 1971. Endangered island plants. Bulletin Pacific Tropical Botanical Garden 1(3): 1-7.
Includes biological reasons for fragility of island ecosystems, and adaptations developed by indigenous Hawaiian flora in isolation from predators.

Fosberg, F.R. 1972a. Man's effects on island ecosystems, pp. 869-880, in Farvar, M.T. and J.P. Milton, eds., The Careless Technology: Ecology and International Development. Garden City, New York: Natural History Press.
Explains destructive acts of man on vegetation.

Fosberg, F.R. 1972b. The axis deer problem. Elepaio 32(9): 86-88.
"Scientifically (speaking),... introducing deer on the island of Hawaii will, in the long run, be a catastrophe with no compensating benefit."

Fosberg, F.R. 1973a. Temperate zone influence on tropical forest land use: a plea for sanity, pp. 345-350, in Meggers, B.J., Ayensu, E.S., and W.D. Duckworth, eds., Tropical Forest Ecosystems in Africa and South America: A Comparative Review. Washington, D.C.: Smithsonian Institution Press.
"Tropical peoples suspect, understandably, that attempts to introduce ideas of conservation and environmental preservation are merely designed to deny them material benefits from rapid exploitation of their resources. Yet, it is distressing to see them repeating the same mistakes that have brought about serious degradation of temperate environments, perpetuating them, in fact, with the increased tempo characteristic of the tropics and augmented by modern technology." Notes stream siltation on Hamakua Coast of Hawaii due to sugarcane plantations on sloping ground inviting runoff.

Fosberg, F.R. 1973b. On present condition and conservation of forests in Micronesia, pp. 165-171, in Planned Utilization of the Lowland Tropical Forests. 263 pp. Pacific Science Association Symposium, 1971, Cipayung, Bogor, Java.
"Forest types which may be regarded as "natural", even though they result from modification of original forest by man, still exist on Guam, Rota, Alamagan, and possibly to a very limited extent on Saipan, in the Marianas, on Babeldaob in the Palaus, on Yap, Truk, Ponape and Kusaie, and on a few of the atolls in the Carolines."

Fosberg, F.R. 1973c. Chapter 13. Vascular plants - widespread island species, pp. 167-169, in A.B. Costin and R.H. Groves, eds. (1973).
Many widespread plant species of the Pacific Islands are polymorphic, comprising several recognizable varieties and forms. These variants should not be destroyed, and many of them have unfortunately already been lost.

Fosberg, F.R. 1973d. Chapter 19. Past, present and future conservation problems of oceanic islands, pp. 209-215, in A.B. Costin and R.H. Groves, eds. (1973).
Discusses catastrophic effects of introduced plants and animals on these islands, where competition from an indigenous equilibrated biota is of minimal effect against the aliens.

Fosberg, F.R. 1975. The deflowering of Hawaii. _National Parks and Conservation Magazine_ 49(10): 4-10.
Recommends that large samples of all kinds of habitat must be preserved if a significant number of Hawaii's endangered plant species is to be saved from extinction.

Fosberg, F.R. 1977. An irresponsible scientific expedition. _Atoll Research Bulletin_ 219: 4-5.
Reports fire-vandalism to _Pisonia_ forest on Vostok Island caused by expedition mounted by government of the Gilbert and Ellice Islands.

Fosberg, F.R. 1979. Tropical floristic botany - concepts and status - with special attention to tropical islands, pp. 89-105, in Larsen, K. and B. Holm-Nielsen, eds., _Tropical Botany_. 453 pp. London: Academic Press.
Makes the useful distinction within destructive weeds, between those able to invade closed, rarely even undisturbed, vegetation, such as _Clidemia hirta_, _Psidium cattleianum_, _P. guajava_, _Paederia foetida_ and _Mikania scandens_ sensu lato, and the category of weeds that are able to occupy open or disturbed areas (habitats) created by man through agricultural, grazing, logging and other activities. Many island endemics have been killed out by plants of the first category in closed vegetation.

Fosberg, F.R. 1983. The human factor in the biogeography of oceanic islands. _C.R. Soc. Biogeographie_ 59(2): 147-190.
Discusses introduction of exotic plants and animals; deforestation; agriculture; fire; and also individually describes the degree of alteration by man which has occurred on each of the principal oceanic islands. "Since the original biogeographic patterns on most islands are not or little understood, ...the nature and effects of man's activities should be carefully and continually documented."

Fosberg, F.R. 1984a. Henderson Island saved. Environmental Conservation 11(2): 183-184.
Stimulated by environmental concerns, the British government declined an offer to partially convert the island to a private development.

Fosberg, F.R. 1984b. Phytogeographic comparison of Polynesia and Micronesia, pp. 33-44, in Radovsky, F.J., Raven, P.H. and S.H. Sohmer, eds., Biogeography of the Tropical Pacific. Bishop Museum Special Publication No. 72. 221 pp.
Includes discussion of anthropic (human) plant geography, and reconstruction of original, pre-human vegetation on high and low islands. Notes that "On oceanic islands,...man's arrival was comparatively recent, and he had already reached the stage where he could build boats, make tools and weapons, use fire, domesticate animals and plants, and thus produce much of his own food." Observes that "if we do not do something soon to protect the remaining vestiges of natural vegetation in the islands, Pacific botany will continue only as herbarium paleobotany."

Fosberg, F.R. 1985. Present state of knowledge of the floras and vegetation of emergent reef surfaces. Proc. Fifth International Coral Reef Congress, Tahiti 2: 138.(Abstract)
"The sad fact, also, is that on almost all coral islands and limestone portions of "high" islands phosphate mining, plantation agriculture, military activities, nuclear weapons testing, introduced feral herbivores and weedy exotic plants, as well as overly dense human settlement have changed the vegetation, eliminated species, and blurred the biogeographic patterns so that island biogeography has become a difficult and uncertain science."

Fosberg, F.R. and G. Corwin. 1985. A fossil flora from Pagan, Mariana Islands. Pacific Science 12: 3-16.
Among other exotic flora, the Jatropha gossypifolia introduced by the Japanese in the 1930's has spread and now dominates large areas in central Pagan.

Fosberg, F.R. and D. Herbst. 1975. Rare and endangered species of Hawaiian vascular plants. Allertonia 1(1): 1-72.
An extensive listing of endangered and threatened plant species, subspecies and varieties, representing one of the more fragile and vulnerable floras on earth.

Fosberg, F.R. and M.-H. Sachet. 1962. Vascular plants recorded from Jaluit Atoll. Atoll Research Bulletin 92: 1-39.

Useful for tracing the spread of introduced plants throughout the Marshall Islands, from pre-German and Japanese times.

Fosberg, F.R. and M.-H. Sachet. 1966. Lebronnecia, gen. nov. (Malvaceae) des Iles Marquises. Adansonia 6(3): 507-510.
Extremely rare and endangered Lebronnecia kokioides is described from Tahuata Island.

Fosberg, F.R. and M.-H. Sachet. 1969. Wake Island vegetation and flora, 1961-1963. Atoll Research Bulletin 123: 1-15.
Observations on disturbance and recovery of vegetation.

Fosberg, F.R. and M.-H. Sachet. 1983a. Henderson Island threatened. Environmental Conservation 10(2): 171-173.
Threatened desecration of a unique biota due to human development activities (later averted by British government).

Fosberg, F.R. and M.-H. Sachet. 1983b. Plants of the Society Islands, pp. 76-107, in Carr, D.J., ed., Sydney Parkinson, Artist of Cook's Endeavour Voyage. 300 pp. Honolulu, Hawaii: University Press of Hawaii.
Parkinson's paintings of plants done in 1769 are useful for documenting species, such as both Hibiscus rosa-sinensis and Miscanthus floridulus on Tahiti, which were members of the Polynesian flora in pre-European times.

Fosberg, F.R. and M.-H. Sachet. 1985. Rare, endangered, and extinct Society Island plants. National Geographic Society Research Reports 21: 161-165.
Approximately 200 out of the total 850 indigenous plant species of the Society Islands are either rare or extinct.

Fosberg, F.R., Sachet, M.-H. and D.R. Stoddart. 1983. Henderson Island (Southern Polynesia): Summary of current knowledge. Atoll Research Bulletin 272: 1-47.
A reasonably unaltered, raised atoll threatened at the time by the spectre of development for human activities. The indigenous flora of Henderson includes 9 species and 6 varieties of endemic angiosperms.

Fowler, L. 1979. Population ecology and impact of the feral burros of Galapagos. Annual Report of the Charles Darwin Research Station 1979: 111-113.
Burros (Equus asinus) were introduced to the Galapagos in the mid-1800's and have become firmly established on all 5 major islands. On Volcan Alcedo (Isla Isabela) the large feral burro population may be overgrazing the vegetation, particularly in the dry season.

Frome, M. 1986. Hawaii's heritage remains at risk. Defenders 61(5): 18-19, 44.
Includes brief discussion of effects of seemingly disadvantageous Hawaiian forestry practices, and status of Hawaiian Volcanoes National Park and proposed geothermal energy complex on the Campbell Estate at Kilauea.

Fullard-Leo, B. 1985. Turtle Bay Hilton: one island, two worlds. Aloha 8(4): 68-70.
Amusements provided for guests at Turtle Bay Hilton and Country Club on Oahu (Hawaiian Islands) include dune-cycling on four-wheeled recreation vehicles along secluded beach and forest trails.

Fullaway, D.T. 1975. Forestry's role in Micronesia. Micronesian Reporter 23(3): 12-15.
Due to domination by a steady succession of foreign powers, some Micronesian societies have been influenced to change from depending on the land for their needs, to a dependency on imported goods, which has affected their attitude towards conservation of land-based resources.

Funk, E. 1982. Unpublished manuscripts. Status reports on Abutilon menziesii Seem. (Malvaceae); Geranium arboreum Gray (Geraniaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Furnas, J.C. 1948. Anatomy of Paradise: Hawaii and the Islands of the South Seas. 542 pp. New York: William Sloane Associates, Inc.
In the Hawaiian Islands, "Sandalwooding left its mark. The hunt for it destroyed a good deal of timberland, as the natives lazily burned the forest to detect stands of it by smell. But far more destructive was the fact that the trade attracted whites, whose very presence was subversive."

Gagne, B.H. 1982. Unpublished manuscript. Status report on Gardenia brighamii Mann (Rubiaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Gagne, W.C. 1975. Hawaii's tragic dismemberment. Defenders 50(6): 461-469.
Causes of threats to fragile ecosystems of Hawaii are portrayed.

Gagne, W.C. 1983. Nihoa: biological gem of the northwest Hawaiian Islands. Ka 'Elele 10(7): 3-5.
The remote environment of the endemic, presumed vulnerable Nihoa loulou palm, Pritchardia remota.

Gagne, W.C. 1986. Hawaii's botanical gardens: panacea or Pandora's box in the conservation of Hawaii's native flora. Newsletter Hawaiian Botanical Society 25: 7-10.
"Some plant groups such as the melastomes and gingers have become sufficiently notorious naturalizers that unanimity would be reached on banning further introductions and coming to grips with the eventual control of the escapees."

Gardiner, J.M. 1979. Silverswords and greenswords from Hawaii. The Garden 104(2): 50-54.
Includes data on Argyroxiphium kauense in cultivation at Royal Botanic Garden, Edinburgh, and cultural requirements of A. sandwicense and A. kauense.

Gardner, T. and P. Gardner. 1985. Rescue in paradise. International Wildlife 15(4):12-13.
Lord Howe I. woodhen saved from threat of extinction presented by feral pigs and goats which were "destroying the thick, wet, forest litter".

Garnock-Jones, P.J. 1978. Plant Communities on Lakeba and southern Vanua Balavu, Lau Group, Fiji. Royal Society of New Zealand Bulletin 17: 95-117.
Man-induced fire, severe soil erosion, and introduced weeds play a part in altering naturally vegetated land here.

Gerrish, G. and D. Mueller-Dombois. 1980. Behavior of native and non-native plants in two tropical rain forests on Oahu, Hawaiian Islands. Phytocoenologia 8(2): 237-295.
Distribution patterns of several exotic species indicate that they may be altering the vegetation structure over large areas in a manner that may reduce the quality of the habitat for endemic plants.

Giffin, J. 1977. Ecology of the feral pig on Hawai'i Island. Elepaio 37(12): 140-142.
"Fern or rain forest habitat is the most extensive feral pig habitat found in the State". Pigs break open tree-fern trunks for starch.

Gilbert, B. 1977. A hellish spot in heavenly surroundings. Audubon 79(2): 30-46.
Article concerns Kalaupapa Peninsula on Molokai I., Hawaiian Is. Discusses "mongrelization" of Hawaiian flora with a "conglomerate of Asiatic, Polynesian, South, Central, North American, Mediterranean, and African species."

Gilbert, C. 1974. The Galapagos and man. Oceans 7(2): 40-47.
Includes remarks on extent of agriculture in the archipelago.

Gillett, G.W. 1972. The critical need for conservation in the Marquesas Islands. Newsletter Hawaiian Botanical Society 11(4): 33-36.
Domesticated and feral grazing animals have largely exterminated the original flora of Nukuhiva, Uahuka, and Uapou.

Gilmartin, A.J. 1970. First colloquium on rare and endangered species of Hawaii. Association for Tropical Biology Newsletter 22: 1-4.
Mentions bulldozing of koa (Acacia koa) forests and replanting them with Eucalyptus in certain areas.

Gilpin, M.E. and J.M. Diamond. 1980. Subdivision of nature reserves and the maintenance of species diversity. Nature 285(5766): 567-568.
Includes reference to Vanuatu (New Hebrides).

Given, D.R. 1975. Conservation of rare and threatened plant taxa in New Zealand: some principles. Proc. New Zealand Ecological Society 22: 1-6.
Includes concise remarks on the status of the Philip Island glory pea (Streblorrhiza speciosa), a presumed extinct legume.

Glassman, S.F. 1957. The vascular flora of Ponape and its phytogeographical affinities. Proc. Eighth Pacific Science Congress 4: 201-213.
A number of endemics in the original vegetation of the comparably sized island of Guam must have been destroyed by man, causing confusion when scientists try to estimate the true, or former, percentage of endemism on Ponape.

Gold, H. 1984. The Galapagos: Seeing what Charles Darwin saw. Islands 4(5): 40-59.
Notes a study of revegetated areas fenced off from goats by personnel of the Galapagos National Park. The Park and the Charles Darwin Research Station are helping to protect the caldera floor of Volcan Alcedo, as well as the cacti of Isla Fernandina, and the pahoehoe lava fields of Isla San Salvador.

Gold, H. 1985. Maui, the isle of the trickster god. Islands 5(2): 20-31.
Includes photographs of Haleakala National Park, and also of recent enormous housing developments on the north coast of Maui at Kahului, and at Kaanapali Beach.

Gon, S.M. 1987. The dunes of Mo'omomi. The Nature Conservancy News 37(1): 14-17.
On the coast of west Molokai, Hawaiian Islands. "Within vast, integrated communities of nearly undisturbed na-

tive grasses and shrubs grow more rare coastal species than in any other single place in the islands."

Gorman, M.L. and S. Siwatibau. 1975. The status of Neoveitchia storckii, a species of palm tree endemic to the Fijian island of Viti Levu. Biological Conservation 8(1): 73-76.
"The species has been reduced to a single population of 150-200 sexually mature trees."

Gormley, R. 1984. Molokai-on the edge. Aloha 7(1): 20-27.
Pineapple plantations are slackening and tourism is increasing, calling for wise land-use in diversified agricultural and development programs so as not to harm the Molokai ecosystem.

Gosnell, M. 1976. The island dilemma. International Wildlife 6(5): 24-35.
On Kauai (Hawaiian Islands) indigenous forests have been cleared for housing developments and for cultivation of Anthurium species and other florist flowers. Also, the introduced European blackberry is a pest there.

Gourou, P. 1963. Pressure on island environment, pp. 207-225, in Fosberg, F.R., ed. (1963).
In the discussion following this article, F.R. Fosberg notes that deforestation and accelerated erosion have had adverse effects on the landscape of Kahoolawe, Lanai, southeast Oahu, and Niihau (Hawaiian Is.).

Gradstein, S.R. and W.A. Weber. 1982. Bryogeography of the Galapagos Islands. Journal Hattori Botanical Laboratory 52: 127-152.
"Because of the destruction of much of the original Scalesia forest (itself a rich habitat), and its replacement by extensively introduced exotic trees and cultivars, this zone (moist evergreen woodland) probably will continue to yield new discoveries of bryophytes and possibly some of them will have been accidentally imported in modern times with animals, fowl, provisions, shoes and pants-cuffs, just as have so many phanerogams."

Grady, M. 1986. Stand structure of an isolated forest in Lyon Arboretum, Oahu, Hawaii. Newsletter Hawaiian Botanical Society 25(2): 47-59.
"Understanding the structural dynamics of small stands can help in planning for nature reserves to prevent extinction of unique forest ecosystems."

Graf, D.F. 1972. American Samoa - Annual Environmental Report. 17 pp. Pago Pago, American Samoa: Office of the Governor.
"With slopes often exceeding 30 percent, the clearing of

vegetation for gardening or home construction generally results in considerable erosion."

Graham, B. 1987 (March 19). Tourism, immigration put strain on Galapagos. Washington Post: A-25.
Pressures from the commercial tourist trade along with a sharp increase in numbers of permanent settlers worry some conservationists that development will be allowed to progress uncontrolled, although government officials indicate that preservation of the islands is important. One senior planner spoke of the desirability of guarding against the "Hawaiianization" of the Galapagos.

Grant, P.R. 1981. Population fluctuations, tree rings and climate. Noticias de Galapagos 33: 12-16.
On Isabela and Santa Cruz (Galapagos), the Bursera populations will eventually collapse unless the feral goats are controlled. A study of individual growth patterns from tree rings will be helpful in assessing the long term survival of Bursera populations.

Green, P.S. 1969. Discussion. Philosophical Transactions Royal Society B255: 616-617.
"Unintelligent burning is a great danger to the plant cover in New Caledonia, almost as great perhaps as the danger from the encroachment of mining, even in the remoter areas in the northern parts of the island."

Green, P.S. 1979. Observations on the phytogeography of the New Hebrides, Lord Howe Island and Norfolk Island, pp. 41-53, in Bramwell, D., ed., Plants and Islands. 459 pp. New York and London: Academic Press.
Only 3 or 4 bushes of Hibiscus insularis now exist in the wild on Philip Island, an island that "presents us with a first-rate example of what man, by means of goats and pigs and finally by rabbits, can do to exterminate a flora."

Green, P.S. 1985. Refound: on South Sea isle. Threatened Plants Newsletter 15: 21.
Abutilon julianae (Malvaceae), extirpated on Norfolk Island, has recently been discovered on Philip Island. Includes observations on condition of Philip vegetation.

Grepin, F. 1976. La medecine Tahitienne traditionnelle. Cahiers du Pacifique 19: 337-382.
Includes list of c.75 traditional medicinal plants of Tahiti, with 14 useful illustrations, and recipes for medications.

Gressitt, J.L., ed. 1963. Pacific Basin Biogeography: A Symposium. 563 pp. Honolulu, Hawaii: Bishop Museum Press.

Groube, L.M. 1971. Tonga, Lapita pottery, and Polynesian

origins. Journal of the Polynesian Society 80(3): 278-316.
Mankind has been occupying Tonga and altering its vegetation to some extent for over 3,000 years.

Guillaumin, A. 1933. Materiaux pour la flore de la Nouvelle-Caledonie, XIII. Revision des Verbenacees. Bull. Soc. Bot. France 80: 476-480.
Briefly traces the introduction and spread of Lantana camara and other verbenaceous weeds in New Caledonia.

Guillaumin, A. 1953a. Mesures de conservation a prendre pour la sauvegarde de la flore de la Nouvelle-Caledonie. (Resume). Proc. Seventh Pacific Science Congress 4: 674.
Urgently recommends establishment of series of integral nature reserves to protect localized plant species.

Guillaumin, A. 1953b. L'evolution de la flore Neo-Caledonienne. Journ. Soc. Oceanistes 9(9): 79-85.
Includes discussion of introduced plants, weeds, forest exploitation.

Guillaumin, A. 1970. Le santal en Nouvelle-Caledonie. Journ. Agric. Trop. Bot. Appl. 17(7-9): 340-341. (Notice (review) by Plessis, J. 1972. Cahiers du Pacifique 16: 214).
Detrimental exploitation of New Caledonian sandalwood had become 230, 563 kg.'s worth in 1908; trade has since ceased.

Gustafson, R.J. 1979. Hawaii's unique and vanishing flora - the genesis of an exhibit. Terra 18(2): 3-9.
Discusses demolishment of Hawaiian flora.

Hall, E.O. 1839. Notes of a tour around Oahu. Hawaiian Spectator 2: 94-112.
Describes lowland vegetation as it was before sugarcane, pineapple, and Prosopis took it over.

Hall, W.L. 1904. The forests of the Hawaiian Islands. USDA Forestry Bulletin 48: 1-29.
Includes notes on forest decline and reforestation.

Halle, F. 1978. Arbres et forets des Iles Marquises. Cahiers du Pacifique 21: 315-357.
Includes discussion of Marquesan forest types which are perpetuated, and encouraged, or modified by human inhabitants.

Halle, N. 1980. Les Orchidees de Tubai (Archipel des Australes, Sud Polynesie). Cahiers de l'Indo-Pacifique 11(3): 69-130.
Cyathea cumingii Baker, the tree-fern of Tubai, is highly endangered. Forests with lesser degradation in

high altitudes contain rare species seemingly in danger of extinction. Contains catalogue of ferns and angiosperms of Austral Is., to which additions are made in the article on vegetation of Rurutu, Halle, N. 1983. Bull. Mus. Nat. Hist. Nat. Paris, ser.4, sect.B., Adansonia 5(2): 141-150.

Hamann, O. 1978. Recovery of vegetation on Pinta and Santa Fe Islands. Noticias de Galapagos 27: 19-20.
Liquidation of goat populations produced recovery of vegetation.

Hamann, O. 1979a. Taxonomic and floristic notes from the Galapagos Islands. Bot. Notiser 132: 435-440.
Callitriche deflexa is a recent introduction which prefers habitats disturbed by goats and pigs. The recent spread of Triumfetta semitriloba may be associated with the continuing disturbance of the natural vegetation caused by feral animals.

Hamann, O. 1979b. Regeneration of vegetation on Santa Fe and Pinta Islands, Galapagos, after the eradication of goats. Biological Conservation 15(3): 215-236.
On Pinta Island about 40,000 feral goats were shot during the period 1971-1977, and as a result of the killings, a rapid regeneration of vegetation in the arid lowlands is underway.

Hamann, O. 1979c. The survival strategies of some threatened Galapagos plants. Noticias de Galapagos 30: 22-25.
Habitat diminishment of Scalesia, Piscidia and Miconia is discussed.

Hamann, O. 1981. Plant communities of the Galapagos Islands. Dansk Botanisk Arkiv 34(2): 1-163.
Grazing goats have degraded the steppe forest in the central arid region of Pinta. Santa Cruz I. has experienced many recent vegetational changes due to introduced plants on new roads, woodcutting, and effects of goats, pigs and donkeys. On Baltra I., it is predicted that desert scrub will dominate due to man's negative influence. On Santa Fe I., goats have devastated the dry-season deciduous steppe forest. The highland plateau of Santa Maria I. is mostly covered with Psidium guajava, an introduced, aggressive competitor. Feral goats are the most serious plague of San Salvador I. The only large island of the Galapagos remaining completely undisturbed by man is Fernandina, which has frequent volcanic eruptions.

Hamilton, L.S., ed. 1983. Forest and Watershed Development and Conservation in Asia and the Pacific. 560 pp. Boulder, Colorado and Essex, England: Westview Press.

Discusses forests and watersheds as natural resources to be conserved as valuable assets.

Hamilton, T.H., Rubinoff, I., Barth, R.H. and G.L. Bush. 1963. Species abundance: natural regulation of insular variation. Science 142: 1575-1577.
Of interest relating to studies of endemism and evolution in the Galapagos.

Harney, T. 1983. Fostering rare breeds on the museum's rooftop. The Torch(Smithsonian Institution) 83(1 January): 2.
The endangered Abutilon sachetianum (Malvaceae) from Marquesas Is. is being grown in National Museum of Natural History's rooftop greenhouse, Washington, D.C.

Harris, D.R. 1962. Invasion of oceanic islands by alien plants. Transactions, Institute of British Geographers 31: 67-82.
Includes pertinent observations on the Pacific Islands.

Harrison, B.C. 1972. The vegetation of Waihoi Valley, East Maui, pp. 94-136, in Kjargaard, J.I., ed., Scientific Report of the Waihoi Valley Project. Sponsored by National Science Foundation. 252 pp. University of Hawaii.
Pastures with remnants of thicket-producing indigenous Dicranopteris linearis (uluhe fern) are often trampled by cattle "until there is nothing but bare earth, almost as if a bulldozer had been at work". "Further introduction of hoofed animals to Maui should be prevented to protect habitats such as Waihoi from being modified." A stand of a possibly new species or variety of Pritchardia palm was mapped.

Hart, A.D. 1975. Living jewels imperiled. Defenders 50(6): 482-486.
Introduced trees, pests and collectors are decimating indigenous land snails (Achatinella) of Hawaii.

Hartley, R.L. 1963. Agriculture on Rotuma Island. South Pacific Bulletin 13(2): 57-61, 63.
On Rotuma I. (politically a part of Fiji Is.) the two most heavily infesting weeds are Lantana camara and Hibiscus tiliaceus. Native "timber is now being used regularly and in large quantities for firing the copra driers."

Hartt, C.E. and M.C. Neal. 1940. The plant ecology of Mauna Kea, Hawaii. Ecology 21(2): 237-266.
Depredations made by feral grazing cattle, goats, sheep, horses and hogs are discussed as biotic factors in the removal of the flora.

Hashimoto, T. 1977. Ogasawara plants with potential for cultivation as ornamentals. Notes Waimea Arboretum 4(1): 12-19.
Interesting data on endemic plants having ornamental qualities suitable for consideration as useful to man.

Hatheway, W.H. 1952. Composition of certain native dry forests: Mokuleia, Oahu, Territory of Hawaii. Ecological Monographs 22: 153-168.
Characteristics and composition of some of the vegetation zones have been altered or destroyed by feral grazing animals and introduced plant pests such as *Prosopis* and *Leucaena*.

Havas, V. 1985a. Galapagos tortoises race progress and flames. Islands 5(5): 10.
Describes adverse effects on environment caused by enormously widespread fire which began in February 1985 when Santo Tomas residents (on Isabela I.) burned diseased coffee plants and the fire inadvertently spread to native vegetation.

Havas, V. 1985b. Next stop, Easter Island. Islands 5(6): 12.
It has been claimed that Easter Island's ecology will not be interfered with by NASA's planned extension of Mataveri airstrip for the purpose of accommodating future aborted launchings of space shuttles from California's Vandenberg Air Force Base.

Hawaii Volcanoes National Park. 1974. National Park Service Silversword Restoration Project Proposal. 15pp. Hawaii Volcanoes National Park, National Park Service, U.S. Department of the Interior.
Concerns conservation of the rare silversword plants of Hawaii (*Argyroxiphium*, Compositae).

Heacox, K. 1984. El cuidado de las Islas Encantadas. Americas 36(6): 2-5, 46-49.
Efforts to prevent adverse impacts from tourism in the Galapagos Islands.

Heine, A. 1984. Urbanization and social change in the Marshall Islands. Ambio 13(5-6): 313-315.
Urbanization has inevitable effects on the surrounding environment.

Heinl, R.D. 1947. The Defense of Wake. 75 pp. Washington, D.C.: U.S. Marine Corps.
Photos depicting effects of 1941 military operations on the vegetation of Wake atoll are included.

Heinl, R.D. and J.A. Crown. 1954. The Marshalls: Increasing the Tempo. 188 pp. Washington, D.C.: U.S.

Marine Corps.
Photos depicting effects of 1944 military operations on the vegetation of the Marshall Islands are included.

Herbst, D.R. 1972a. Botanical survey of the Waiehu sand dunes. Bulletin Pacific Tropical Botanical Garden 2(1): 6-7.
Includes information on Hawaiian Scaevola coriacea.

Herbst, D. 1972b. Ohai, a rare and endangered Hawaiian plant. Bulletin Pacific Tropical Botanical Garden 2(3): 58.
Sesbania tomentosa on leeward shores is presently threatened by motorcyclists and the proposed construction of a highway which would open the area to greater disturbance.

Herbst, D. 1976. Appendix B-2. Vegetation survey of the Barbers Point Harbor Area, Oahu. 3 pp. Final Environmental Impact Statement, Barbers Point Harbor, Oahu, Hawaii. Honolulu, Hawaii: U.S. Army Engineers.
Mentions endangered plant species in the area.

Herbst, D. 1977a. Endangered Hawaiian plants. Newsletter Hawaiian Botanical Society 16(1-2): 22-29.
"A kapu placed on cattle allowed the build-up of enormous herds until their destruction (of vegetation) was so great that man was forced to contain or destroy them."

Herbst, D. 1977b. Vanishing plants. Water Spectrum 9(4): 20-26.
Includes discussion of vanishing elements of Hawaii's indigenous flora.

Herbst, D. 1980. Miscellaneous notes on the Hawaiian flora.I. Phytologia 45(1): 67-81.
Includes notes on spread of introduced weeds near LORAN station on Tern Island, French Frigate Shoals.

Herbst, D. 1984. Cooke's kokio (Kokia cookei). Endangered Wild Flower Calendar. Brooklyn, New York: Department of Biology, Brooklyn College.
Includes descriptive caption material.

Herbst, D. and J.J. Fay. 1981 (30 January). Proposal to list Panicum carteri (Carter's Panicgrass) as an endangered species and determine its critical habitat. Federal Register 46(20): 9976-9979.
Includes range map of Panicum carteri on Mokoli'i Island, Hawaiian Islands.

Hertlein, L.G. 1963. Contribution to the biogeography of Cocos Island, including a bibliography. Proc. California

Academy of Science 32(8): 219-289.
Cocos I., in the Pacific Ocean off Central America: discussion of biotic environment.

Hess, W.N. 1962. New horizons in resource development. Geographical Review 52: 1-24.
Illustrates nuclear blast devastation on Enewetak.

Heyerdahl, T. 1940. Marquesas Islands. Proc. Sixth Pacific Science Congress 4: 543-546.
At the time, nature protection was lacking in the Marquesas. In some places, semiwild animals were devouring plants and bringing in weeds which then developed and spread along trails.

Heyerdahl, T. 1963. Prehistoric voyages as agencies for Melanesian and South American plant and animal dispersal to Polynesia, pp. 23-35, in Barrau, J., ed., Plants and the Migrations of Pacific Peoples." 136 pp. Honolulu, Hawaii: Bishop Museum Press.
Remarks on a single dwarfed, mutilated living specimen of *Sophora toromiro* in the Rano Kao crater, the only individual remaining of this Easter Island endemic, are included.

Heyerdahl, T. 1968. The prehistoric culture of Easter Island, pp. 133-140, in Yawata, I. and Y.H. Sinoto, eds., Prehistoric Culture in Oceania: A Symposium. Honolulu, Hawaii.
Refers to evidence of forest plants existing when period of human occupation began.

Heyligers, P.C. 1967. Vegetation and ecology of Bougainville and Buka islands, pp. 121-145, in: CSIRO (Australia), Lands of Bougainville and Buka Islands, Territory of Papua and New Guinea. CSIRO Land Research Series No. 20. 184 pp. Melbourne: CSIRO.
Essential to any future studies of vegetation change on Bougainville (formerly in Solomon Islands politically), and includes descriptions of anthropogenous vegetation types. Land-use map accompanies entire publication.

Heywood, V.H. 1979. The future of island floras, pp. 431-441, in Bramwell, D., ed., Plants and Islands. London: Academic Press.
General considerations of the fate of insular plants are presented.

Hickman, J. 1985. The Enchanted Islands: The Galapagos Discovered. 169 pp. Dover, New Hampshire: Tanager Books.
Chapter 16: Conservation of Species, includes discussion of alien plants, and introduced animals such as the 100,000 goats and 20,000 pigs of Santiago Island in the Galapagos.

Higashino, P.K., Guyer, W. and C.P. Stone. 1983. The Kilauea Wilderness Marathon and Crater Rim runs: sole searching experiences. Newsletter Hawaiian Botanical Society 22: 25-28.
Contestants from the weed-ridden island of Oahu were prevented from inadvertently spreading weed seeds on the soles of their running shoes, prior to participating in a foot-race on the island of Hawaii.

Hirano, R.T. 1973. Preservation of the Hawaiian flora. Arboretum and Botanical Gardens Bulletin 7(1): 10-11.
Contains general remarks on the title subject.

Hirano, R.T. and K.M. Nagata. 1972. A Checklist of Indigenous and Endemic Plants of Hawaii in Cultivation at the Harold L. Lyon Arboretum. 22 pp. University of Hawaii, Harold L. Lyon Arboretum.
165 taxa are being cultivated for the preservation and study of a rapidly diminishing Hawaiian flora.

Hobdy, R. 1976. Hawaiian ecosystems, pp. 17-18, in Department of Planning and Economic Development, Industrial Forestry for Hawaii. 40 pp. Honolulu, Hawaii.
The need for a timber industry (commercial forestry) in Hawaii is discussed relative to a managerial commitment to protect proposed endangered plant species.

Hodel, D. 1980. Notes on Pritchardia in Hawaii. Principes 24(2): 65-81.
Several species of Pritchardia palm are highly localized endemics and threatened in Hawaii.

Hoffman, C.W. 1950. Saipan: The Beginning of the End. 286 pp. Washington, D.C.: U.S. Marine Corps.
Illustrates effects of 1944 military operations on vegetation.

Hoffman, C.W. 1951. The Seizure of Tinian. 169 pp. Washington, D.C.: U.S. Marine Corps.
Illustrates effects of 1944 military operations on vegetation.

Holden, C. 1985. Hawaiian rainforest being felled. Science 228: 1073-1074.
Ohi'a trees (Metrosideros) on 3,300-acre tract of Campbell Estate on island of Hawaii are threatened by conversion of habitat to grazing lands.

Holdgate, M.W. and E.M. Nicholson. 1967. An international conservation programme for the Pacific Islands. Micronesica 3(1): 51-54.
Lists 9 principal conservation problems.

Holdgate, M.W. and N.M. Wace. 1961. The influence of man on the floras and faunas of southern islands. The Polar Record 10(68): 475-493.
Includes Juan Fernandez Is., where problems of goats were enough to cause severe soil erosion on Masafuera.

Holdsworth, D.K. 1974. A phytochemical survey of medicinal plants in Papua New Guinea, Part I. Science in New Guinea 2(2): 142-154.
The author has investigated medicinal plants of numerous Melanesian islands politically in Papua New Guinea.

Holing, D. 1987. Hawaii: the Eden of endemism. The Nature Conservancy News 37(1): 6-13.
Discussion of Hawaii's unique biota, and of factors which contribute to its high percentage of endemism. Vulnerability to threats from introduced species and human disturbance are mentioned.

Holt, R.A. 1981. Unpublished manuscript. Status report on *Gouania hillebrandii* Oliver (Rhamnaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plant of the Hawaiian Islands.

Holt, R.A. 1983a. Exotic species control: an island perspective. The Nature Conservancy News 33(4): 23-24.
Includes *Clidemia hirta*, an objectionable melastomataceous weed of Hawaii.

Holt, R.A. 1983b. The Maui Forest Trouble: A Literature Review and Proposal for Research. Hawaii Botanical Science Paper No. 42. 67 pp. Honolulu, Hawaii: University of Hawaii.
Widespread canopy dieback in Hawaiian and other Pacific rainforests is discussed.

Holthus, P.F. 1985. A reef resource conservation and management plan for Ponape Island (Caroline Archipelago, Micronesia). Proc. Fifth International Coral Reef Congress 2: 184.(Abstract)
Includes consideration of habitat degradation from sand extraction.

Holzner, W.M., Werger, J.A. and I. Ikusima, eds. 1983. Man's Impact on Vegetation. 370 pp. The Hague, The Netherlands: Dr. W. Junk BV Publishers.
Many basic principles and problems are presented for evaluation and discussion.

Hosaka, E.Y. 1936. A troublesome introduced grass. Mid-Pacific Magazine (April-June): 126.
Chloris divaricata or "star grass", native to Australia, is a troublesome, destructive invader of Honolulu lawns where it replaces the "Bermuda grass", *Cynodon dactylon*.

Hosmer, R.S. 1910. Kahoolawe Forest Reserve. Hawaiian For. Agr. 7: 264-267.
Imputes a local climatic change due to destruction of Kahoolawe vegetation.

Hosokawa, T. 1967. Life-form of vascular plants and the climatic conditions of the Micronesian islands. Micronesica 3: 19-30.
Human disturbance of vegetation may cause confused speculation as to the original sequence of seral stages in plant succession towards climax vegetation.

Hosokawa, T. 1973. On the tropical rainforest conservation to be proposed in Micronesia, pp. 150-164, in Planned Utilization of the Lowland Tropical Forests. 263 pp. Pacific Science Association Symposium, 1971, Cipayung, Bogor, Java.
Recommends the conservation of mossy forests near summits of Mt. Nanarant and Mt. Niinioanii and near the top of Mt. Fenkol in Kusiae; of the Planchonella forests on uninhabited Palauan islands; of any remaining Campnosperma forests on Palau and Ponape; and of any remaining Terminalia carolinensis forests on Kusaie.

Hough, F.O. 1947. The Island War: The United States Marine Corps in the Pacific. 415 pp. Philadelphia and New York: J.B. Lippincott Company.
World War II destruction of vegetation on Pacific Islands, often as a direct or side-result of attempts to extricate opposing troops from fortified limestone caves, was accomplished with apparatus including portable one-man flamethrowers; napalm-throwers mounted on amphtracks (tracked landing vehicles) or on the turrets of tanks; and by attaching bulldozer blades to tanks and armored amphtracks (amphibious tanks) in order to clear operating positions.

Hough, F.O. 1950. The Assault on Peleliu. 209 pp. Washington, D.C.: U.S. Marine Corps.
Illustrates effects of 1944 military operations on the vegetation of Peleliu.

Hough, F.O. and J.A. Crown. 1952. The Campaign of New Britain. 220 pp. Washington, D.C.: U.S. Marine Corps.
Illustrates effects of 1944 military operations on the vegetation of New Britain.

Howard, R.A. 1962. Hawaii - a botanical and horticultural opportunity. Garden Journal 12(6): 223-226.
Discusses land use and the need for preservation of natural areas in Hawaii.

Howard, W.E. 1965. Control of Introduced Mammals in New

Zealand. 96 pp. New Zealand DSIR, Information Series, No. 45.
Unstable habitat conditions caused by introduced noxious animals such as sheep and deer in New Zealand are discussed, and should exemplify the repercussions awaiting similar ill-conceived introductions contemplated in the Pacific.

Howarth, F.G. 1972. Ecological Studies on Hawaiian Lava Tubes. 20 pp. Island Ecosystems IRP/IBP Hawaii, Technical Report No.16. Honolulu, Hawaii: University of Hawaii.
The forest overlying many of the caves has been cut or removed, thus drastically altering the ecology of the caves beneath. Also, regrettably , the fields with the largest caves known on Kauai were covered to a depth of 5 meters by sugar cane bagasse (pressed cane-stem trash) and the caves are now gone and their fauna extinct.

Howarth, F.G. 1973. The cavernicolous fauna of Hawaiian lava tubes, 1. Introduction. Pacific Insects 15(1): 139-151.
The forest over the tube of Kazumura Cave (Island of Hawaii), one of the largest known lava tubes in the world, has recently been altered by fire and cutting for a housing subdivision and is now a swampy savanna with Metrosideros trees. Many of the tree roots are dead but still hang from the ceiling of the cave. Significance: Tree roots dangling in cave-air function to supply food and form pathways for percolation of organically rich water which supports life of cave organisms.

Howe, K.R. 1984. Where the Waves Fall: A New South Sea Islands History From First Settlement to Colonial Rule. 400 pp.
Includes detailed consideration of the Melanesian sandalwood trade from 1840's to end.

Hoyle, M.A. 1978. Forestry and conservation in the Solomon Islands and the New Hebrides. Tigerpaper 5(2): 21-24.
Interactions of forest management and conservation practices.

Hughes, P.J. and G. Hope. 1979. Prehistoric man-induced degradation of the Lakeba landscape: evidence from two inland swamps. Unesco/UNFPA Fiji Island Reports 5. Canberra: Australian National University.
Lakeba I. is in the Lau group of the Fiji Islands.

Huguenin, B. 1974. La vegetation des Iles Gambier: releve botanique des especes introduites. Cahiers du Pacifique 18(2): 459-471.
Lists 200 plant species introduced in Mangareva I., western Polynesia.

Hunt, P.F. 1969. Orchids of the Solomon Islands. Philosophical Transactions Royal Society B255: 581-587.
Some of the coastal orchids of Koloombangara I. in the Solomon Is. were brought from New Georgia and Giza by the native Melanesians and Gilbertese. This activity of collecting orchids and then cultivating them somewhere else could possibly affect future understanding of the true pattern of island orchid endemism in the area. A similar concern for the possible mix-up in geographical ranges resulting from human introduction of a plant is evidenced by the note on the palm Pelagodoxa henryana Beccari by E.J.H. Corner, loc. cit. 592-593 (1969).

Hurlimann, H. 1953. Etude sur la structure des forets de la Nouvelle-Caledonie: Experiences et propositions. Et. Melan. n.s. 5(7): 55-68.
Includes considerations of plant conservation in New Caledonia.

Hurlimann, H. 1959a. Naturschutzbestrebungen in Pazifik. Schweizer Naturschutz 4: 123-127.
Includes history of vegetation disturbance in Pacific islands, and specifically relates the threat of inundation in the Plaine des Lacs, New Caledonia.

Hurlimann, H. 1959b. Need for a conservation park in New Caledonia. Proc. Ninth Pacific Science Congress 7: 50.
A proposed large hydroelectric project to create artificial lakes would inundate most flat and swampy areas of the Plaine de Yate and Plaine des Lacs in New Caledonia. This process would exterminate the serpentine endemics, especially Podocarpus palustris, Dacrydium guillauminii, and perhaps also Libocedrus yateensis.

Hurlimann, H. 1960. Un parc de conservation botanique en Nouvelle-Caledonie. Jour. Soc. Oceanistes 16: 110-112.
Transplantation of threatened New Caledonian plants has been attempted.

Iltis, H.H. 1967. Whose fight is the fight for nature? Sierra Club Bulletin 52(9): 34-39.
Invokes the expression by Edgar Anderson, that "Taxonomists are mice hiding behind herbarium cases hating each other", in order to persuade taxonomists to reject irresponsibly arrogant attitudes towards plant conservation.

IUCN (International Union for Conservation of Nature and Natural Resources).Headquarters: Gland, Switzerland.

IUCN Commission on National Parks and Protected Areas (CNPPA). 1982a. IUCN Directory of Neotropical Protected Areas. Dublin, Ireland: Tycooly International Publishing Ltd.

Discusses (pp. 194-196) the Galapagos National Park and World Heritage Site.

IUCN Commission on National Parks and Protected Areas (CNPPA). 1982b. The World's Greatest Natural Areas: An Indicative Inventory of Natural Sites of World Heritage Quality. 70 pp.
Universal significance of 220 sites around the world is described, including: Marine lakes of Palau (Republic of Belau), Village of Nan Madol (Caroline Islands), Rapa Nui National Park (Chile), Island of Tahiti (France), Rennell Island (Solomon Islands), Savo Island (Solomon Islands), Kulambangara Island (Solomon Islands), Hawaii Volcanoes National Park (USA), Le Pupu-Pue National Park (Western Samoa), Lord Howe Island, Juan Fernandez National Park (Chile), and Galapagos National Park (Ecuador).

IUCN Conservation Monitoring Centre (CMC). 1983a(3 January). List of Hawaiian Threatened and Endemic Plants Recorded in Cultivation. 12 pp. Royal Botanic Gardens, Kew, England.
In addition to this Hawaiian list, the CMC has prepared lists for the Galapagos and Juan Fernandez Islands (1984).

IUCN Conservation Monitoring Centre (CMC). 1983b. Background Notes on the Hawaiian Flora. 4 pp. Royal Botanic Gardens, Kew, England.
Includes data on main threats to the flora, conservation measures taken, and lists of parks, refuges, and botanical gardens of relevance to plant conservation in Hawaii.

IUCN Conservation Monitoring Centre (CMC). 1985. The Botanic Gardens List of Rare and Threatened Species of the Hawaiian Islands. Botanic Gardens Conservation Coordinating Body Report No. 14. 21 pp. Royal Botanic Gardens, Kew, England.
Lists 274 rare and threatened Hawaiian endemic plants in cultivation in Hawaiian botanical gardens and other gardens throughout the world.

IUCN Conservation Monitoring Centre (CMC). 1986a (3 April). List of CCAL References for Pacific. 10 pp. Royal Botanic Gardens, Kew, England.
This unpublished computer-generated list contains many references to articles published in the Federal Register and the Endangered Species Technical Bulletin concerning proposed and officially listed endangered and threatened plant species of Hawaii and elsewhere in the American Pacific. Updated lists are produced upon request to CMC.

IUCN Conservation Monitoring Centre (CMC). 1986b. The

Plant Sites Red Data Book. 48 pp. Royal Botanic Gardens, Kew, England.
Outline of a book-concept from the Threatened Plants Unit, containing paragraphs describing candidate plant conservation localities in Hawaii, Galapagos, Juan Fernandez Is., Fiji, New Caledonia, Marquesas, Rapa (Austral Is.), and Western Caroline Is.

Jacobi, J.D. 1978. Vegetation Map of the Kau Forest Reserve and Adjacent Lands, Island of Hawaii. 1 sheet. Resource Bulletin PSW-16. Berkeley, California: Pacific Southwest Forest and Range Experiment Station.
This map outlines areas of "introduced shrub-dominated community", often with a disturbed understory dominated by Psidium cattleianum (guava).

Jacobi, J.D. 1981. Vegetation Changes in a Subalpine Grassland in Hawaii Following Disturbance by Feral Pigs. 23 pp. Cooperative National Park Resources Studies Unit, Technical Report 41. University of Hawaii at Manoa.
In Haleakala National Park, native and introduced plant species competed equally for areas uprooted by pigs.

Jacobs, M. and T.J.J. de Boo. 1982. Conservation Literature on Indonesia: Selected, Annotated Bibliography. 274 pp. Leiden, The Netherlands: Rijksherbarium.
Comprises references to literature on all aspects of conservation in Indonesia. Geographical coverage includes Papua New Guinea, and thus of interest regarding the adjacent Bismarck Archipelago.

Jenkin, R.N. and M.A. Foale. 1968. An Investigation of the Coconut-Growing Potential of Christmas Island. Volume 1. The Environment and the Plantations. 123 pp. Land Resource Study No. 4. Land Resources Division, Directorate of Overseas Surveys, Tolworth, Surrey, England.
Christmas Island, in the Gilbert and Ellice Islands Colony, had an almost complete lack of trees for natural reasons before coconuts were planted, "the exception being the occurrence of a few buka trees, Pisonia grandis, on Motu Tabu and near the South-East Point, though the latter were virtually destroyed by the 1957 atomic test." It is also observed that recent clearing for coconut planting has largely destroyed the Messerschmidia argentea - Sida fallax association.

Jenkins, D.W. 1975. At last, a brighter outlook for endangered plants. National Parks and Conservation Magazine 49(1): 13-17.
Includes discussion and photos of endangered Hawaiian plant species, e.g. Hibiscus kahilii.

Jenkins, D.W. and E.S. Ayensu. 1975. One-tenth of our

plant species may not survive. Smithsonian 5(10): 92-96.
Includes discussion of several endangered Hawaiian plants, e.g. Rollandia and Argyroxiphium.

Jenkins, J.T. 1948. Bibliography of whaling. Journal, Society for the Bibliography of Natural History 2(4): 71-166.
Whalers were sometimes the first non-indigenous people to variously discover, describe, explore, exploit, or adversely impact certain remoter Pacific islands.

Johannes, R.E. 1985. The value today of islanders' traditional knowledge of their natural resources. Pandanus Periodical 7: 3 pp.
Traditional knowledge of wise land use and of medicinal herbs is being lost, and Pacific islanders should be encouraged to retain such knowledge.

Johnson, C.G., Alvis, R.J. and R.L. Hetzler. 1960. Military Geology of Yap Islands, Caroline Islands. 164 pp. Tokyo: H.Q. US Army Pacific.
"Southernmost Yap Island was once cleared by the Japanese and planted to gardens and (citrus) orchards. This area has been lying fallow since 1945 and the whole area is grown over by low brush and very dense stands of tall grass (Ischaemum muticum L.) and weeds."

Johnson, M.P. and P.H. Raven. 1973. Species number and endemism: the Galapagos Archipelago revisited. Science 179: 893-895.
Includes explanation of patterns of plant endemism among the 29 Galapagos islands.

Johnson, S.P. 1972. Palau: conservation frontier of the Pacific. National Parks and Conservation Magazine 46(4): 12-17.
Describes efforts to protect Palau's ecosystem, threats to which include brush fires, soil erosion, and phosphate mining.

Johnston, E.G. 1975. A review of literature on native medicine in Micronesia with emphasis on Guam and the Mariana Islands. Guam Recorder 5(2): 60-65.
Includes articles on role of traditional medicinal plants in health-delivery systems of various islands.

Johnston, W.B. 1959. The Cook Islands. Journal of Tropical Geography 13: 38-57.
"Few remnants of the original tropical rain forest have survived and, even in the interior, the larger forest members have been milled for building material and for boxwood."

Josiah, S.J. 1983. Guam's badlands. Glimpses of Micronesia

23(2): 32-35.
"Overgrazing by livestock, bulldozing and recreational vehicles are speeding up the erosion process."

Judd, C.S. 1916. Kahoolawe, pp. 117-125, in Thrum, T.G., compiler, Hawaiian Almanac and Annual for 1917. Honolulu, Hawaii: T.G. Thrum.
Relates the history of vegetation destruction by feral animals on Kahoolawe Island.

Judd, C.S. 1921. Hawaiian forests and trails. Hawaiian Forester and Agriculturist 18: 79-82.
Seeds of Paspalum conjugatum grass were accidentally introduced and the plants have invaded forests.

Judd, C.S. 1922. Honolulu watershed protection. Hawaiian Forester and Agriculturist 19: 30-45.
Hawaiian wet forests are very susceptible to destructive influences that retard their utility as a useful watershed.

Judd, C.S. 1927a. The natural resources of the Hawaiian forest regions and their conservation. Hawaiian Forester and Agriculturist 24(2): 40-47.
Includes history of sandalwood exploitation, and effects of sugarcane cultivation and cattle grazing.

Judd, C.S. 1927b. Factors deleterious to the Hawaiian forest. Hawaiian Forester and Agriculturist 24(2): 47-53; B.P. Bishop Museum Special Publication 12: 11-12.
Discusses deforestation of Oahu watershed by overgrazing. On the island of Hawaii, land cleared for coffee and subsequently abandoned is occupied by invasive Hilo grass.

Judd, C.S. 1927c. Hawaiian forest regions and their conservation. B.P. Bishop Museum Special Publication 13: 9.
"The damage done to the forests during the period of the sandalwood trade and by the cattle which were allowed to run wild, together with the clearing and cultivation of large tracts of land, have reduced the forests to a point where they are not even adequate to protect our water supply."

Judd, C.S. 1927d. Bamboo against staghorn fern. Hawaiian Forester and Agriculturist 24(2): 54-55.
Bamboo (Bambusa vulgaris) which was planted in a reforestation experiment on Maui where natural forest had died out, has displaced invasive staghorn fern (Gleichenia linearis) in some places.

Judd, C.S. 1936. Growing sandalwood in the Territory of Hawaii. Journal of Forestry 34(1): 2 pp.

Native species of sandalwood, once largely extirpated for trade, are increasing in population size due to protection from scorching fires and grazing animals.

Judd, C.S. 1937. Staghorn fern invasion. *B.P. Bishop Museum Special Publication* 31: 8-9.
"Although the *uluhi* or staghorn fern (*Gleichenia linearis*) makes a fair cover for water conservation, it has two undesirable qualities. It invades the native forest with a dense mat which prevents natural reproduction, and in dry seasons this mat presents a serious fire menace."

Judd, C.S. 1940. Forest resources of the Territory of Hawaii, U.S.A. *Proc. Sixth Pacific Science Congress* 4: 797-800.
Along dry seashores is found the *algaroba* forest type, comprising introduced *Prosopis juliflora* which has run wild on 100,000 acres, and is interspersed with plants such as the prickly pear cactus (*Opuntia*).

Juvik, J.O. and S.P. Juvik. 1984. Mauna Kea and the myth of multiple use, endangered species and mountain management in Hawaii. *Mountain Res. Devel.* 4(3): 191-202.
Considerations for effective use of natural resources of the Hawaiian mountainous areas.

Kalkman, C., ed. 1983. People unite against Unilever. *Flora Malesiana Bulletin* 36: 3916-3917.
"The people of North New Georgia, Solomon Islands, have become aware of the damage a large timber operator like Levers Pacific can do to their forests."

Karasik, G. 1984. Smiley Ratliffe: some men are islands. *Islands* 4(5): 16-17.
An excursion into the mentality of an individual who proposed to acquire rights to Henderson Island for partial clearance and settlement.

Kastadalen, A. 1982. Changes in the biology of Santa Cruz Island between 1935 and 1965. *Noticias de Galapagos* 35: 7-12.
Regarding introduced plants, it is noted that avocados (*Persea americana*) crowd out all native vegetation where they become established, and so do *Hibiscus tiliaceus* and *Eugenia jambos*.

Kawamura, K., Tanaka, T. and T. Inagaki. 1940. On the soils of the Saipan, Tenian, and Rota Islands, Marianas. Part I and II. *Jour. Sci. Soil and Manure* 14: 439-484. (Translation by U.S. Geological Survey, 1949).
Includes data on changes in soil conditions after deforestation.

Kay, E.A. 1972. Hawaiian natural history: 1778-1900, pp. 604-653, in Kay, E.A., ed., A Natural History of the Hawaiian Islands - Selected Readings. Honolulu, Hawaii: University of Hawaii Press.
Includes much useful background information on Hawaiian environment.

Keast, A. 1966. Australia and the Pacific Islands - A Natural History. New York: Random House.
Chapter 10 on Hawaii, Tahiti, Society Is., Samoa, Tonga, Marquesas; Chapter 11 on atolls such as Bora Bora, Tuamotu; Chapter 12 on Melanesia and Lord Howe Island.

Keck, C.B. 1957. Visit to Eniwetok. Proc. Hawaiian Entomological Society 16: 188.
So much of Eniwetok's topsoil was removed during World War II that even ants are absent from the land.

Kemf, E. 1985. The Galapagos fire: 50 years' damage. World Wildlife Fund News 37: 8.
During the 3-month long fire on Isabela Island, the introduced pest tree, guava (Psidium guajava), contributed to the massive forest destruction in a curious way: "Fire burning in these trees often advanced against the wind because the oil in the plants ignited rapidly and spread destruction to surrounding vegetation."

Kenchington, R. 1985. Coral-reef ecosystems: a sustainable resource. Nature and Resources 21(2): 18-27.
Reef animal species suffer indirectly through "land-based events such as deforestation."

Kikukawa, H.H. and R.K. LeBarron. 1971. Ohia-lehua. Aloha Aina 2(2): 12-13.
Metrosideros collina (ohia-lehua) and koa forests have been destroyed by cattle grazing in some areas of the Hawaiian Islands.

Kimura, B.Y. and K.M. Nagata. 1980. Hawaii's Vanishing Flora. 88 pp. Honolulu, Hawaii: Oriental Publishing Co.
Colored photos and detailed status coverage of 56 official and candidate endangered and threatened species, including at least one literature reference for each treated plant.

King, J. 1978. Hawaii's wildlife - legacy and stewardship. Elepaio 38(11): 122-125.
Mentions detrimental effects of goats, farming, and weedy Clidemia and Passiflora on native ecosystems.

King, W. 1971. Hawaii: haven for endangered species? National Parks and Conservation Magazine 45(10): 9-13.
Indigenous Hawaiian vegetation of dryland forests was

sequentially ravaged and denuded by grazing and browsing introduced mammals, then by European settlers who indiscriminately cleared land for sugarcane and pineapple plantations, then by cattle which were encouraged to enter the forests, and then followed by goats eating everything within reach.

King, W.B. 1973. Conservation status of Central Pacific islands. Wilson Bulletin 85: 89-103.
Includes information of interest to vegetational status in various islands.

Kinnane, J. 1983. People of Pitcairn. Oceans 16(5): 42-51.
Notes that feral "goats...are a nuisance because they crop the vegetation too close and cause erosion."

Kira, T., Ogawa, H. and K. Yoda. 1962. Some unsolved problems in tropical forest ecology. Proc. Ninth Pacific Science Congress 4: 124-134.
With data included from Ryukyus, it is shown that an unavoidable limitation is imposed upon temperate zone methods of agriculture when they are employed under tropical climatic regimes. Implications of this observation regarding the fall in productivity (ecosystem metabolism) caused by forest destruction are discussed.

Kirch, P.V. 1980. Polynesian prehistory: cultural adaptation in island ecosystems. American Scientist 68(1): 39-48.
Notes that prehistoric Polynesian burning of forest cover and similar sequences of forest destruction due to Polynesian agriculture have a cumulative effect in transforming the landscape of Polynesian islands.

Kirch, P.V. 1982a. Transported landscapes. Natural History 91(12): 32, 34-35.
"Both the purposeful and the inadvertent introductions to Hawaii of a range of competitive species by the Polynesians provide a classic example of what the botanist Edgar Anderson called "man's transported landscapes". Not only did the Polynesians surround themselves with an imported flora and fauna; they also undertook to actively modify and manipulate their insular environment according to cultural concepts that they had inherited from their ancestors in the South Pacific and, ultimately, Southeast Asia."

Kirch, P.V. 1982b. Ecology and the adaptation of Polynesian agricultural systems. Archaeol. Oceania 17: 1-6.
On Mangareva, Easter Island, and Kahoolawe, environmental degradation, often through radical reduction of forest, shrub and grassland communities, led to various innovations in agricultural techniques and other

forms of repercussion.

Kirch, P.V. 1982c. The impact of the prehistoric Polynesians on the Hawaiian ecosystem. Pacific Science 36(1): 1-14.
Polynesian impact was greater than heretofore realized. "The cumulative effects of forest clearance and habitat modification through the use of fire led to major changes in lowland ecology." Includes long, excellent bibliography.

Kirkpatrick, J.B. and D.C. Hassall. 1981. Vegetation of the Sigatoka sand dunes, Fiji. New Zealand Journal of Botany 19(3): 285-297.
The native closed-forest "formation has been drastically reduced in area by firing, cutting, grazing, and the instability of the parabolic dune system in the high-energy coastal environment. The closed-forest may be eliminated if the present pattern of use of the area continues or if the full area of the dunes is used for mining of magnetite.

Kluge, P.F. 1969a. The landscape of war. Micronesian Reporter 17(1): 19-25.
The intensive battle of Peleliu in the Palau Is., 1944, caused great damage to the landscape and vegetative cover, as shown by photos in this article.

Kluge, P.F. 1969b. The beaches of Saipan. Micronesian Reporter 17(2): 21-32.
Includes specifications as to which Saipan beaches are not yet overgrown with tangantangan weed-trees, or littered with tourist garbage.

Kluge, P.F. 1969c. Tinian: island in waiting. Micronesian Reporter 17(3): 34-36.
The atomic bombs which destroyed the Japanese cities of Hiroshima and Nagasaki in 1945 originated from the loading pits of Tinian, a coral island in the Marianas. For such purposes, Tinian had been largely transformed into an aircraft staging ground by the Seabees. At present, those roads and runways are choked with weeds, sharing the land with ranched cattle and pigs.

Kluge, P.F. 1986. Palau: problems in the Pacific. Smithsonian 17(6): 44-55.
Includes a substantial discussion of current environmental pressures on Palau.

Knapp, R. 1975. Vegetation of the Hawaiian Islands. Newsletter Hawaiian Botanical Society 14(5): 95-121.
Includes discussion of changes in the vegetation since the discovery of the Hawaiian Islands by Europeans, and of 8 types of plant communities developed as a conse-

quence of those changes.

Knibb, D. 1984. Pioneer project in the Pacific. American Forests 90(10): 39-40, 51-53.
Teak on Savaii.

Kobayashi, H.K. 1973. Present status of the ahinahina or silversword, *Argyroxiphium sandwicense* DC. on Haleakala, Maui. Newsletter Hawaiian Botanical Society 12(4): 23-26.
About 40,000 individuals of this plant are present, and the population is impacted by insect larval damage to seeds, vandalism by visitors, and goat browsing. See O. Degener, *op. cit.* 13(1): 1-2 (1974) for related data.

Kobayashi, H.K. 1974. Preliminary investigations on insects affecting the reproductive stage of the silversword (*Argyroxiphium sandwicense* DC., Compositae), Haleakala Crater, Maui, Hawaii. Proc. Hawaii Ent. Soc. 21(3): 397-402.
Insect larvae destroy the plant's seeds.

Kochi, J.S. 1971. Objectives and importance of conservation. Atoll Research Bulletin 148: 21-22.
Lists eleven ways to enrich the natural resources of Palau.

Koford, C.B. 1966. Economic resources of the Galapagos Islands, pp. 286-290, in Bowman, R.I., ed., The Galapagos. Berkeley and Los Angeles, California: University of California Press.
Discusses introduced animals of Galapagos.

Konishi, T., Kondo, N. and A. Yoshida. 1979. *Kokia cookei*: extinction or survival? Notes Waimea Arboretum 6(1): 2-5.
Efforts to save endangered Hawaiian malvaceous plant.

Koopowitz, H. and H. Kaye. 1983. Plant Extinction: A Global Crisis. 239 pp. Washington, D.C.: Stone Wall Press, Inc.
Seed banks could be employed to save Hawaiian and other Pacific plant species.

Kores, P. 1979. A review of the literature on Hawaiian orchids. Newsletter Hawaiian Botanical Society 18(3-5): 34-55.
Includes notes on the rare endemic *Habenaria holochila*.

Kramer, P. 1973. Wildlife conservation in the Galapagos Islands (Ecuador). Nature and Resources 9(4): 3-10.
Includes discussion of agricultural practices, introduced plants, and other problems of direct human pressure on vegetation.

Kramer, P. 1974. Galapagos conservation: present position and future outlook. Noticias de Galapagos 22: 3-5.
Three goats were introduced onto Isla Pinta in 1957. By 1971, more than 30,000 of their descendants had been exterminated by the Park Service.

Kramer, P. 1983. The Galapagos: islands under siege. Ambio 12(3-4): 186-190.
Comprehensive account of environmental disturbances in the Galapagos.

Kramer, R. 1969. We're botching conservation! Do you care? Elepaio 29(11): 98-101.
Includes discussion of effects of feral grazing animals on Hawaiian vegetation.

Kroon, A.H. 1953. Forestry in Western Samoa: a review. South Pacific Bulletin 3(3): 29-30.
Photos include clearing of forests, and of forest margin and areas of shifting cultivation being invaded by vines and secondary species.

Kuroda, N. 1954. Report on a trip to Marcus Island with notes on the birds. Pacific Science 8(1): 84-93.
The island is presently in a "totally disfigured" condition due to human intervention in the form of troop garrisons, etc. in World War II.

Kurrus, T. 1985. Uncle Sam in paradise. Aloha 8(2): 48-55.
U.S. Navy destroyers will now limit their use of the island of Kahoolawe for target practice to a small section of the island, and the Navy has promised to affect repairs wherever damage was done to the terrain. The 5 principal branches of the U.S. Armed Services own or control over 260,000 acres of land on 6 Hawaiian islands, including 25 percent of the land on Oahu. Environmental and land-use conflicts between the services and civilians sometimes erupt.

Kuschel, G. 1963. Composition and relationship of the terrestrial faunas of Easter, Juan Fernandez, Desventuradas, and Galapagos Islands, pp. 79-95, in Galapagos Islands: A Unique Area for Scientific Investigations. Occasional Papers California Academy of Sciences, No. 44.
Zoological article includes notes on impoverishment of the floras.

Lal, P.N. 1984. Environmental implications of coastal development in Fiji. Ambio 13(5-6): 316-321.
Negative impact may result unless proper precautions are taken on coastal Fiji.

Lamb, K.P. and J.L. Gressitt, eds. 1976. Ecology and Conservation in Papua New Guinea. Pamphlet No. 2. Wau Ecology Institute, Papua New Guinea.
Of related interest to the Bismarck Archipelago.

Lamoureux, C.H. 1961. Botanical observations on Leeward Hawaiian atolls. Atoll Research Bulletin 79: 1-10.
On Kure Atoll, there are 4 types of area disturbed by weed invasions: margins of roads and landing strip; albatross runways; clearings around living quarters; and clearing around the radio tower.

Lamoureux, C.H. 1963a. Vegetation of Laysan. Proc. Hawaiian Academy of Science 37(1961-1962): 22.
Introduction of rabbits to Laysan in 1903 caused the number of native higher plant species to drop from 25 in 1896, to 13 in 1911, to 4 in 1923. In 1923 the rabbits were exterminated, and a 1961 expedition found 17 native plant species on Laysan.

Lamoureux, C.H. 1963b. The flora and vegetation of Laysan Island. Atoll Research Bulletin 97: 1-12.
Introduction of rabbits in 1903 resulted in their multiplying to consume most of the native vegetation, and to convert the island into a wasteland by 1923, when they finally succumbed to starvation. The island was then replanted, and the natural vegetation also recovered.

Lamoureux, C.H. 1964. The Leeward Hawaiian Islands. Newsletter Hawaiian Botanical Society 3(2): 7-11.
Includes history of denudation and revegetation of Laysan Island.

Lamoureux, C.H. 1968. Should the axis deer be introduced to the island of Hawaii? Elepaio 29(2): 10-15.
Opposes introduction of deer on aesthetic, recreational, economic, and scientific grounds.

Lamoureux, C.H. 1973a. Plants, pp. 63-66, in University of Hawaii (Department of Geography). Atlas of Hawaii. Honolulu, Hawaii: University Press of Hawaii.
Includes considerations of rare plant conservation.

Lamoureux, C.H. 1973b. Chapter 28. Conservation problems in Hawaii, pp. 315-319, in Costin, A.B. and R.H. Groves, eds. (1973).
The 7 major categories of problems are: land development; land clearing for roads and housing sites; beach "improvement" projects; water development projects; expansion of pasture lands; timber (native species replacement); and hunting.

Lamoureux, C.H. 1976a. Trailside Plants of Hawaii's

National Parks. 80 pp. Hawaii Natural History Association.
"Lantana, originally brought to Hawaii as a garden ornamental in 1958, escaped from cultivation and has become a major pest(in agricultural and pasture lands) at elevations up to 4,000 feet."

Lamoureux, C.H. 1976b. Endangered species in Hawaii, effect on other resource management: a response. Newsletter Hawaiian Botanical Society 15(1): 14-21.
Calls for integration of plant conservation concerns and good forest resource management practices.

Lamoureux, C.H. 1981. Unpublished manuscript. Status report on Kokia drynarioides (Seem.) Lewt. (Malvaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Lamoureux, C.H. 1982. Unpublished manuscripts. Status reports on Mezoneuron kavaiense (Mann) Hdb. (Fabaceae); Munroidendron racemosum (Forbes) Sherff (Araliaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Landgraf, L.K. 1973. Mauna Kea and Mauna Loa silversword: alive and perpetuating. Bulletin Pacific Tropical Botanical Garden 3(4): 64-66.
Argyroxiphium sandwicense is on Maui and Hawaii; A. kauense only on Hawaii; and A. caliginii only on Maui.

Langlois, A.C. 1976. Supplement to Palms of the World. 252 pp. Gainesville, Florida: University Presses of Florida.
Discusses status of populations of the palm Taveunia trichospadix Burret on island of Taveuni, Fiji, "...when we arrived at Taveuni in 1966, the area below an elevation of 1,000 ft. (above which the coconut will not thrive) had been converted into one large coconut grove. This very considerable planting of coconut palms, involving the complete destruction of the native forest, evidently eliminated whatever stands of Taveunia that may have existed previously. What the planters did not do, the hogs and rats did, so that very reduced numbers of T. trichospadix are now confined to, and above, the cloud line."

Lasseter, J.S. and C.R. Gunn. 1979. Vicia menziesii Sprengel(Fabaceae) rediscovered: its taxonomic relationships. Pacific Science 33(1): 85-101.
Last collected in 1915 on island of Hawaii and regarded as extinct until rediscovered in 1973.

Lawcock, L. 1982. Guam's young conservationists. Glimpses of Micronesia 22(1): 32-37.
Helping to combat further degradation of the Guamanian

ecosystem.

Lawesson, J.E. 1986. Problems of plant protection in the Galapagos. Noticias de Galapagos 44: 12-13.
Problems include damage caused by introduced animals (goats, pigs, donkeys, cattle); rising demands of the human population for timber, which result in threats to stands of *Piscidia carthagenensis*; and spread of pernicious exotic plants such as guava, cinchona, lantana, avocado, and passion fruit, which variously affect the indigenous *Miconia* and *Scalesia* zones.

Laycock, G. 1970. Haunted sands of Laysan. Audubon 72(2): 42-49.
Mentions the almost total destruction of the vegetation by rabbits.

LeBarron, R.K. 1962. Eucalypts in Hawaii: A Survey of Practices and Research Programs. 24 pp. Pacific Southwest Forest and Range Experiment Station, Miscellaneous Paper No. 64.
More than 100 species of *Eucalyptus* have been introduced into Hawaii. "Eucalypts excel many, although not all, other trees in Hawaii in their ability to overtop and quickly outgrow competing vegetation."

LeBarron, R.K. 1966. The program and objectives of the Hawaiian Division of Forestry. Elepaio 26(8): 67-69.
Contains statistics on land ownership, acreage and usage.

LeBarron, R.K. 1970. Saving Hawaii's forests. Aloha Aina 1(1): 7-8.
Serious pests getting into forests include cattle, and blackberry vines which smother native vegetation.

LeBarron, R.K. 1971a. A forester's point of view. Aloha Aina 2(2): 6-11.
Illustrates an exclosure to keep grazing animals away from the rare na'u tree, *Gardenia remyi*, in Hawaiian Islands.

LeBarron, R.K. 1971b. Kahoolawe. Aloha Aina 2(2): 16-20.
The Hawaiian island of Kahoolawe's vegetation suffers from suppression and overgrazing by feral sheep and goats; deterioration from soil erosion; and use as a U.S. Navy bombing target. There is "unexploded ordnance (ammunition) virtually all over the island."

Lee, K.E. 1969. Some soils of the British Solomon Islands Protectorate. Philosophical Transactions, Royal Society B255: 21-257.
"Indiscriminate burning of Santa Isabel and San Jorge has resulted in baring of the soil surface over

considerable areas, and loss of surface soil horizons by sheet and gully erosion." Lee believes the fires are set as a form of entertainment.

Lee, M.A.B. 1974. Distribution of native and invader plant species of the island of Guam. Biotropica 6(3): 158-164.
"The type of invading species and the organization of native species into communities appear to be important factors in the success of plant invasion."

Leigh, J., Briggs, J. and W. Hartley. 1981. Rare or Threatened Australian Plants. Canberra, Australia: Parks and Wildlife Service.
Includes lists of 69 species of endemic flowering plants and ferns for Lord Howe I. and 49 species for Norfolk and Philip I.

Levathes, L.E. 1983. Kamehameha - Hawaii's warrior king. National Geographic 164(5): 558-599.
Describes some land-use problems.

Lever, R.J.A.W. 1953. Distribution of fauna species in Oceania. Fiji Society of Science and Industry 3: 70-77.
Contains mention of goats being introduced to Henderson Island.

Lever, R.J.A.W. 1964. Savo, British Solomon Islands Protectorate. South Pacific Bulletin 14(3): 41-42.
"Primary jungle is now found only some distance inland from the villages, which are all situated on the coast and linked by a passable road."

Levine, J. 1984. Islands of life. National Wildlife 22(3): 56-63.
Concerns the volcanic coasts of Hawaiian Islands.

Lewin, R. 1978. Galapagos: the endangered islands. New Scientist 79(1112): 168-171.
The threat of ecological disaster now hangs over the islands as a result of human colonization.

Libby, K. 1969. The promised voyage. Micronesian Reporter 17(1): 29-39.
Pictorials on the devastated landscape and obliterated vegetation of Bikini Atoll when Bikini was recolonized after radioactivity levels subsided in 1968.

Liem, D. 1977. Wildlife utilisation in the proposed Garu Wildlife Management Area, pp. 285-292, in Winslow, J.H., ed., The Melanesian Environment. 562 pp. Canberra: Australian National University Press.
The study area is on the north coast of West New Britain. "It must be remembered that with the

disappearance of the forest stands, the wildlife protein supply, minor forest products (rattan) and other forest plants utilised for social, cultural or medicinal purposes will also be lost or considerably reduced."

Lindsey, R. 1986. Hawaii issue: how much tourism is too much? The New York Times, 13 March 1986: A10.
Environmentalists on the Big Island of Hawaii have lost a court complaint in which it was asserted that the construction of a $360 million hotel complex featuring tramways and Venetian-style canals and gondolas, would tend to unfavorably alter the natural environment.

Linge, T. 1983. Un jeune biologiste americain se preoccupe de la sauvegarde de la vegetation d'origine. La Depeche (newspaper), p. 23.
Interview with Gustav Paulay regarding his plant conservation efforts on the island of Rurutu, French Polynesia.

Linklater, E. 1974. The Voyage of the Challenger. 288 pp. London: Sphere Books Ltd.
At the time of the voyage of the Challenger in 1872-1876, no trees were found below an elevation of 700 feet on Juan Fernandez I., since all trees originally growing up to that altitude had previously been cut down to provide fuel.

Linney, G.K. 1982. Unpublished manuscripts. Status reports on Alectryon macrococcus Radlk. (Sapindaceae); Drypetes phyllanthoides (Rock) Sherff (Euphorbiaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Little, E.L., Jr. 1969. Native trees of Hawaii. American Forests 75(2): 16-17,44-45.
Includes trees of plant communities which are being impacted by habitat alteration.

Little, H.P. 1982. The Nature Conservancy of Hawaii's endangered forest and bird project, pp. 355-358, in McNeely, J.A. and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Washington, D.C.: Smithsonian Institution Press.
Concerns endangered bird species whose habitats are endangered due to "biological dismemberment" of the ecosystem by man.

Lodge, O.R. 1954. The Recapture of Guam. 214 pp. Washington, D.C.: U.S. Marine Corps.
Includes photographs of effects of World War II military operations on the vegetation.

Long, Senator O.E. 1960. Sheep destruction of woodland. Bulletin Conservation Council for Hawaii 1(2): 4.
Forests on the upper slopes of Mauna Kea are being destroyed by feral sheep. Includes statistics on sheep population increase.

Loope, L.L. and C.P. Stone. 1984. Introduced vs. native species in Hawaii, a search for solutions to problems of island biosphere reserves, pp. 283-288, in Unesco/UNEP. Conservation, Science and Society. Paris.
Exploration of a perennial problem in Hawaiian plant habitat conservation.

Lowry, J.B. 1973. Phytochemical prospecting and conservation of lowland tropical rainforest, pp. 248-252, in Planned Utilization of the Lowland Tropical Forests. Pacific Science Association Symposium, 1971, Cipayung, Bogor, Java. 263 pp.
A plant's "secondary metabolites" or "natural products" may provide important starting materials for the manufacture of chemical compounds useful to man. Examples from Dacrydium (Podocarpaceae) and Connaropsis (Oxalidaceae) are included.

Lucas, G. 1980. Deux cas remarquables de taxa menaces: Cyprinodontinae nord-africains, Araucaria neo-caledoniens. C. R. Soc. Biogeographie 56(489): 51-52.
Intensification of destruction and exploitation of lateritic soils in New Caledonia for nickel mining would increasingly threaten the several Araucaria species occurring there.

Lucas, G. L. and H. Synge, compilers. 1978. The IUCN Plant Red Data Book. 540 pp. Morges, Switzerland: IUCN.
Includes data on status in the wild, in cultivation, and in protected areas, of numerous endangered and vulnerable plant species native to the Pacific islands, e.g., species from Lord Howe I., Gambier Is., Hawaiian Is., Henderson I., Juan Fernandez Is., Guam, Easter I., Marquesas, New Caledonia, Philip I., and Fiji Is.

Lucas, S.A. 1981. Recent introductions of ornamental value. Bull. Pacific Tropical Botanical Garden 11(1): 8-13.
Includes young plants of Sophora toromiro (Leguminosae), an Easter Island endemic which is extinct in the wild due to the introduction of sheep to the island.

Lyon, H.L. 1918. The forests of Hawaii. Hawaiian Pl. Rec. 18: 276-280.
Observations on Hawaiian forest destruction.

Lyon, H.L. 1919. Some observations on the forest problem of Hawaii. Hawaiian Pl. Rec. 21: 289-300.

Problems associated with Hawaiian reforestation are noted.

Lyon, H.L. 1922. Hawaiian forests. Hawaiian For. Agr. 19: 159-162.
Discusses vegetation dynamics of Hawaii and invasion of Paspalum conjugatum grass.

Lyon, H.L. 1927. Botany in Hawaii. B. P. Bishop Museum Special Publication 12: 10-11.
Indicates the reasons why Hawaiian forests are extremely sensitive to invasion by stock.

Lyon, H.L. 1929. Forestry on Oahu. Hawaiian For. Agr. 26: 11-15.
Problems involving re-establishment of forests on watersheds of Oahu are discussed.

MacCaughey, V. 1918. The Hawaiian sumach. Torreya 18: 183-188.
This lowland plant is being reduced by competition from introduced plants.

MacCaughey, V. 1918-1919. History of botanical exploration in Hawaii. Hawaiian For. Agr. 15: 388-396, 417-429, 508-510 (1918); 16: 25-28, 49-54(1919).
In 31 brief chapters, the author mentions, where appropriate, "the original introductions of the grazing animals which have been the most influential single factor in the alteration of the Hawaiian vegetation."

MacDaniels, L.H. 1947. A study of the fe'i banana and its distribution with reference to Polynesian migrations. B. P. Bishop Museum Bulletin 190: 1-56.
Among the causes of disappearance of wild fe'i banana strains from some Tahitian valleys: the fe'i are eaten by wild cattle and hogs; the plants are smothered by weeds such as Lantana and wild morning-glory.

MacDaniels, L.H. 1952. New Caledonia: a warning. Cornell Plantations 8: 40-44.
Grasslands and forests are subjected to uncontrolled burning, causing disaster to the vegetation.

Mack, J. 1975. Hawaii's first natural area reserve. Defenders 50(6): 500-503.
Concerning Ahihi-Kinau reserve on Maui.

Mackensen, G. and D. Hinrichsen. 1984. A "new" South Pacific. Ambio 13(5-6): 291-294.
Contains good background material for understanding present conditions in the Pacific.

Mangenot, G. 1963. The effects of man on the plant world,

pp. 117-132, in Fosberg, F.R., ed. (1963).
Includes discussion by H.M. Johnson which mentions disturbance problems of Hawaiian vegetation.

Mann, H. 1866. Denudation on the Hawaiian Islands. Proc. Boston Society Natural History 10: 232-234.
General observations on threats to native vegetation.

Manner, H.I., Thaman, R.R. and D.C. Hassall. 1984. Phosphate mining induced vegetation changes on Nauru Island. Ecology 65(5): 1454-1465.
Analysis of the extent to which vegetation has been established on the disturbed open-pit phosphate-mined areas of Nauru.

Maragos, J.E. and M.E. Elliott. 1985. Coastal resource inventories in Hawaii, Samoa and Micronesia. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 235. (Abstract)
Inventories provide baseline data to develop resource conservation plans.

Marden, L. 1957. I found the bones of the Bounty. National Geographic 112(6): 725-789.
Notes that Pitcairn Island is deforested, and that Pitcairners do their woodcutting on uninhabited Henderson Island.

Marsh, J.A. 1979. Book review of Scagel, R.F., ed., Mankind's Future in the Pacific (1975). Micronesica 15(1 & 2): 335-337.
Mentions the book's articles by I.M. Cowan on "Biota Pacifica 2000", M. Strong on "Environment and man's future in the Pacific"; W. Epstein on "The environmental impact of weapons use and testing."

Marshall, A.G. 1973. A start to nature conservation in the New Hebrides. Biological Conservation 5(1): 67-79.
Preliminary conservation efforts are discussed, with map. Reef I., the only atoll in the group, is a proposed nature reserve.

Marshall, A.G. and Lord Medway. 1976. A mangrove community in New Hebrides, South-West Pacific. Biological Journal Linnean Society 8(4): 319-336.
Notes human alteration of mangrove vegetation by planting coconuts, etc. at Port Stanley, Malekula, New Hebrides.

Marshall, C. 1949a (Reprinted 1966). Report on Forestry in the Trust Territory of the Pacific Islands. 94 pp. Scientific Investigations in Micronesia, SIM Report No. 14. Trust Territory of the Pacific Islands: Division of Land Management, Department of Resources and Development.

Includes examples to follow up the statement that "With the coming of Euro-Asiatic Iron-Age culture, the natives (in high Pacific islands) were suddenly enabled to attack the forest and destroy their land and soil almost as efficiently as the people of the Middle East, the Nile Valley, the Mediterranean, India, China and America have destroyed the natural resources of their lands."

Marshall, C. 1949b. Forestry problems of the South Pacific. Agricult. Journal (Fiji) 20(4): 1-7.
Includes description of forest degradation in Fiji Is.

Marshall, C. 1953. Forestry problems of the South Pacific. Proc. Seventh Pacific Science Congress 6: 267-277.
A well-rounded account with plea to respect ecological stability of forest ecosystems, emphasizing Fijian conditions.

Marshall, C. 1961. Forestry, conservation and land tenure in Southeast Asia and the Pacific. Proc. Eighth Pacific Science Congress 6: 222-225.
It is asserted that, at the time (1953), a cause of bitter political criticism was the refusal of the British administration in Fiji to permit the more astute immigrant businessmen of Europe, India and China to acquire the right to destroy land.

Marshall, D. 1961. Ra'ivavae - "High Island". Pacific Discovery 14(2): 2-8.
Includes an interpretation of the vegetation disturbance history of Ra'ivavae in Polynesia.

Mason, L. 1979. Socioeconomic development and ecosystem integrity in American-controlled Pacific Island locations, pp. 10-1 - 10-27, in Byrne, J.E., ed. (1979).
Includes discussion of disruptive activities and their ecological effects. Topics are typhoons and other natural disasters; changing subsistence technologies; commercial development of agriculture and fisheries; transportation facilities; tourism and industrial development; war; and urbanization.

Massal, E. and J. Barrau. 1956. Some lesser-known Pacific food plants. South Pacific Bulletin 6(3): 17-18.
Hitherto underexploited native plants with seeming potential for wider utilization include Gnetum gnemon from the New Hebrides.

Matsue, H. 1932. Ten Year History of South Sea Islands Exploitation. 239 pp. Tokyo, Japan. (In Japanese).
History of clearance of vegetation of Tinian and planting of sugar cane as a replacement, with photos.

Matthiessen, P. and R. Wenkham. 1970. Kipahulu - from

cinders to the sea. Audubon (May, 1970): 14 pp.
Includes a plea to save the dense wilderness rainforests of the Kipahulu Valley on Maui, Hawaiian Islands.

Maxwell, J. 1985. Paniolos, the cowboys of Hawaii. Islands 5(4): 78-80.
In order to control the depredations of herds of wild cattle, John Palmer Parker was given an official land grant in 1847 by King Kamehameha III of Hawaii, to bring the cattle under domestication. Thus began the Parker Ranch, now the largest singly owned ranch in the United States, comprising 225,000 acres with 45,000 cattle.

McClelland, C.K. 1915. Grasses and Forest Plants of Hawaii. 43 pp. Hawaii Agricultural Experiment Station Bulletin No. 36.
"The cactus known as prickly pear, or panini (Opuntia sp.), is one of the important forage crops of Hawaii. On some ranches there are large areas fairly well covered with this plant. On Ulupalakua, for example, there are 2,000 acres; on the Haleakala Ranch 1,500 acres; on leeward Hawaii 10,000 acres."

McCombs, P. 1987 (March 15). Cousteau and the capture of Paradise. Washington Post : G1-G6.
On Raoul I. (Kermadec Is.) there is a program to eradicate weedy plants, including buttercup, passion-fruit and 30-40 other species, which are taking over and strangling the indigenous plants. Thus far, 35,000 buttercup plants have been dug out or treated.

McCracken, R.J. 1953. A preliminary report on the soils of Saipan, Mariana Islands. Pacific Science 7(3): 267-277.
"The original vegetation of Saipan...was greatly decimated by extensive clearing for sugar cane culture during the period of Japanese control."

McGorum, P. 1975. The trouble with tourists. Defenders 50(6): 516-520.
Includes an interview with the botanists Dr. and Mrs. O. Degener of Hawaii. Tourists inadvertently introduce exotic plant species to the islands; they also bring increased incentives for developers to construct warrens to accommodate their future visits.

McHarg, I.L. 1971. Man: Planetary Disease. 28 pp. Washington, D.C.: Agricultural Research Service, U.S. Department of Agriculture.
We must learn to live in peaceful co-existence with the biota in our ecosystem. Mankind's predatory disposal of passive species would suggest that we are a persistent, contaminating, contagious and lethal parasite of the world's natural vegetation.

McHugh, D. 1986. Recovering the Galapagos. 3 pp. IUCN Feature Stories. Gland, Switzerland: IUCN Press Sevice.
Santiago I. has 100,000 goats and 20,000 pigs, causing much destruction of natural vegetation. The recovery of Pinta I. after the annihilation of 40,000 goats has been marvelous, and erosion halted as well.

McIntire, E.G. 1960. Canton Island (Phoenix Islands). 42 pp. Library brochure prepared for the Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
"Nearly half of the land area of Canton Island has been disturbed by man and his activities during the last two decades...much of the area which has been disturbed remains bare of any vegetation."

McIntire, E.G. 1961. Hawaiian Islands, With Special Reference to Kaneohe Bay, Oahu; South Point, Hawaii; Waimea District, Kauai. 73 pp. Library brochure prepared for the Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
"Little natural vegetation is left on the lower slopes of the mountains in the southern and western parts of Kauai, since nearly all suitable land has been planted to sugar cane or pineapple."

McKinney, J. 1983. Haleakala and Hawaii Volcanoes: from the sublime to the ridiculous. Islands 3(2): 20-32.
Includes discussion of feral goat damage in Haleakala National Park (Maui), and undesirable exotic plants such as pine, gorse and thistle.

McKinney, J. 1985. Bombs away, Kahoolawe. Islands 5(1): 10.
An Hawaiian environmentalist group claims that the 1985 RIMPAC maneuvers (shelling, anti-submarine, torpedo and counter-vessel activities) conducted near Kahoolawe by the United States, Australia, New Zealand, Canada, and Japan, may have adversely impacted the environment which already suffers from uncontrolled devouring of vegetation by feral goats. The island's pristine reefs are said to be dying from the runoff of the eroded soil and ashes of explosives.

McKinney, J. 1986. Kauai: a journey through the Garden Isle. Islands 6(2): 38-59.
The Hawaiian island of Kauai attempts to achieve economic security through development, without destroying the fragile landscapes. Article discusses prospects of selling Kauai-grazed buffalo (bison) meat to Japan; also, mentions exotic trees of Waimea Canyon including California redwood, Australian *Eucalyptus*, and Japanese sugi pine.

McMakin, P.D. 1977. Shoreline Erosion on Guam: A Position Paper. 4 pp., in Guam Coastal Management Program Technical Reports, Vol. II. Agana, Guam: Bureau of Planning.
The practice of sand mining for construction, landfill and golf course purposes has degraded several beaches in terms of reduced ecological complexity, aesthetic appearance and recreational potential.

McMichael, D.F. and F.H. Talbot. 1970. Conservation of islands and coral reefs of the Great Barrier Reef system, the islands of the Coral Sea, and Norfolk and Lord Howe Islands. Micronesica 5(2): 493-496.
Human impacts threaten the indigenous terrestrial floras on Norfolk and Lord Howe islands.

McQueen, D.R. 1983. Notes on the ecology of Nothofagus aequilateralis in New Caledonia. Tuatara 26(2): 62-69.
"Nothofagus aequilateralis is a tree of low to medium altitudes in New Caledonia. It does not form extensive forests but is in isolated patches over a wide geographic range, suggesting fragmentation by man-induced fires."

Melville, R. 1979. Endangered island floras, pp. 361-377, in Bramwell, D., ed., Plants and Islands. London and New York: Academic Press.
Contains examples of endangered plants from the Pacific Ocean islands.

Menard, W. 1982. To find Niihau. Oceans 15(5):16-20.
On the privately owned and protected Hawaiian island of Niihau, the people are contented to live within the stabilizing requirements of their own population carrying capacity, as determined by water availability. Attempts to achieve sensible adjustment to prevailing environmental conditions could well be instituted in the more destitute semi-arid regions of the world.

Merlin, M.M. 1985. Woody vegetation in the upland region of Rarotonga, Cook Islands. Pacific Science 39(1): 81-99.
Although the indigenous coastal and lowland vegetation is absent or in a very disturbed condition, alteration of the native upland forest has been comparatively mild.

Merrill, E.D. 1940. Man's influence on the vegetation of Polynesia, with special reference to introduced species. Proc. Sixth Pacific Science Congress 4: 629-639; reprinted in Chronica Botanica 10(3-4): 334-345 (1946).
Guam was an important area for the introduction and spread of economic and weedy plants from various points abroad.

Mid-Pacific Marine Laboratory. 1975. Mid-Pacific Marine

Laboratory, Enewetak, Marshall Islands. 25 pp. Kaneohe, Hawaii: Mid-Pacific Marine Laboratory.
Subsequent to World War II damage, "the (Enewetak) flora was further decimated by the 43 atomic events that took place during the U.S. test program."

Milne, C.A. and M.D. Steward. 1967. The inheritance of land rights in Laura, 45 pp., in Mason, L., ed., The Laura Report. Honolulu, Hawaii: University of Hawaii.
People of Laura, a large village on Majuro Atoll in the Marshall Islands, recognise 25 categories of land ownership and acquisition. Efforts to exploit, or to preserve land for conservation purposes in this and similar communities, will have to take the existence of such categories into consideration.

Milton, J.P. 1968. Introduction: The islands and the meaning of diversity, pp. 22-36, in Porter, E. and K. Brower, Galapagos - The Flow of Wildness, vol. 2: Prospect. 187 pp. San Francisco, New York, London: Sierra Club.
Includes some discussion of effects of introduced animals and plants on the indigenous vegetation.

Mitchell, F. 1981. Mouflon sheep and Kau silversword. Notes Waimea Arboretum 8(1): 6.
"The mouflon sheep introduced into Hawaii in 1973 have now become very noticeable in the area of the Kau silversword on Mauna Loa, Hawaii."

Mohlenbrock, R.H. 1983. Where Have All The Wildflowers Gone? 239 pp. New York: Macmillan Publishing Co., and London: Collier Macmillan.
Includes discussion of such Hawaiian endangered plants as *Kokia cookei*, *Lipochaeta venosa*, and *Vicia menziesii*.

Moir, W.W.G. 1971. Objective Secured. 22 pp. Honolulu, Hawaii: Hawaiian Botanical Gardens Foundation, Inc.
Describes the background and struggles by the Hawaiian Botanical Gardens Foundation to secure a national charter for the Pacific Tropical Botanical Garden, among whose objects and purposes is: "to collect and cultivate tropical flora of every nature and origin and to preserve for the people of the United States species of tropical plant life threatened with extinction."

Moldenke, H.N. 1968. The vervains collected on the Galapagos Islands by Charles Darwin during the voyage of the "Beagle". Phytologia 16(4): 340-342.
Notes that the introduced *Verbena litoralis* "is now quite abundant in many parts of the island group and appears to be spreading in the manner of introduced "weeds"."

Montgomery, S. 1972. Feral animals. Newsletter Hawaiian Botanical Society 11(2): 13-16.
Surveys the concern over the impact of hooved animals on native Hawaiian vegetation.

Moomaw, J.C. and M. Takahashi. 1960. Vegetation on gibbistic soils in Hawaii. Journal Arnold Arboretum 41: 391-411.
Gibbistic soils of Kauai, which have high alumina and iron content, have long been exploited and therefore support very degraded plant communities on the acidic ground.

Moore, D.M. 1983. Human impact on island vegetation, pp. 237-246, in Holzner, W., Werger, M.J.A. and I. Ikusima, eds., Man's Impact on Vegetation. The Hague: Dr. W. Junk Publishers.
Mentions Hawaiian Islands and New Caledonia. Discussion topics include levels of endemism, environmental stability, mechanical interference with plant cover, grazing animals, and alien plants.

Moore, H.E. 1966. Palm hunting around the world. IV. Lord Howe Island. Principes 10: 13-21.
This island is known for the endemic Belmore sentry palm (Howea belmoreana, synonym: Kentia belmoreana) and the Forster sentry, or kentia, palm (Howea forsterana, synonym: Kentia forsterana).

Moore, H.E. 1969. Satakentia: a new genus of Palmae-Arecoideae. Principes 13(1): 3-12.
In a protected grove of Satakentia liukiuensis on Ishigaki Island (Ryukyus), these palms have probably grown from seedlings which remained after mature palms were cut for the "cabbage", or edible terminal bud, during World War II.

Moore, H.E. 1979. Endangerment at the specific and generic levels in palms. Principes 23(2): 47-64.
Includes discussion of status of New Caledonian Pritchardiopsis and Fijian Neoveitchia.

Moore, H.E. and N.W. Uhl. 1984. The indigenous palms of New Caledonia. Allertonia 3(5): 313-402.
Pritchardiopsis jeanneneyi Beccari was rediscovered in 1980, having been presumed extinct because penal convicts detained at the Bay of Prony in the 1890's cut the plants for the edible palm "cabbage", and subsequent searches until 1980 were unsuccessful.

Moore, P.H. 1974. Guam's flora: rare ferns of Guam. Guam Rail 8(8): 5.
On Guam, Cyathea lunulata "is in constant danger during the dry season, of being destroyed by fire except in the

vicinity of Fena Lake where it is still protected by the Navy." Includes discussion of Angiopteris durvilleana.

Moore, P.H. 1980. Notes on the endangered species of Guam. Notes Waimea Arboretum 7(1): 14-16; followed by Daguio, C., Checklist of plants growing at Waimea Arboretum (1980) collected by P.H. Moore, loc. cit. 16-17.
Only 4 adult trees of the endemic Serianthes nelsonii are known to exist on Guam, and the plant has been extirpated from Rota.

Moore, P.H. and P.D. McMakin. 1979. Plants of Guam. 186 pp. University of Guam, Cooperative Extension Service.
Coverage of topics includes erosion in the Savannah, and the effects of introduced mammals in limestone forests.

Moore, P.H., Raulerson, L., Chernin, M. and P. McMakin. 1977. Inventory and Mapping of Wetland Vegetation in Guam, Tinian and Saipan, Mariana Islands. Department of Biosciences, University of Guam.
Species endangered in Guam include Lumnitzera littorea, Bruguiera gymnorrhiza, Xylocarpus moluccensis, and Rhizophora mucronata.

Moore, W.R. 1945. Gilbert Islands in the wake of battle. National Geographic 87: 129-162.
Includes photos of vegetation after invasion during World War II military operations in the Pacific Combat Theater.

Morat, P. and J.-M. Veillon. 1985. Contribution a la connaissance de la vegetation et de la flore de Wallis et Futuna. Adansonia 3: 259-329.
Over large areas, forest vegetation destroyed by clearing and by fire is replaced by various types of secondary vegetation, including an unusual heath vegetation over certain repeatedly burned soil types.

Motooka, P.S., Saiki, D.F., Plucknett, D.L., Younge, O.R. and R.E. Daehler. 1967. Control of Hawaiian jungle with aerially applied herbicide. Down to Earth 23(1): 18-22.
Efforts to eradicate exotic vegetation are discussed; some indigenous vegetation is harmed in the process.

Moverley, A.V. 1953. Pitcairn Island: an economic survey. Transactions and Proceedings of The Fiji Society 4(3): 61-67.
On Pitcairn, "Deforestation is practically complete except for a small area on the northwest side, and timber is now not available locally for building houses and boats or even coffins."

Mueller-Dombois, D. 1967. Ecological relations in the alpine and subalpine vegetation of Mauna Loa, Hawaii.

Journal Indian Botanical Society 46(4): 403-411.
Grazing by cattle and goats, and uprooting by pigs with subsequent invasion by introduced grasses, has interfered with the original vegetation here.

Mueller-Dombois, D., ed. 1972. Island Ecosystems Stability and Evolution Subprogram. IBP/IRP Technical Report No. 2. 262 pp. Honolulu, Hawaii: University of Hawaii.
Includes coverage of every form of biological threat to the vegetation of Hawaii; excludes treatment of tourism effects.

Mueller-Dombois, D. 1973a. Natural Area System Development for the Pacific Region, A Concept and Symposium. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 26. 55 pp. Honolulu, Hawaii: University of Hawaii.
The concept and role of parks and ecological reserves in a Pacific natural area system is discussed.

Mueller-Dombois, D. 1973b. A non-adapted vegetation interferes with water removal in a tropical rain forest area of Hawaii. Tropical Ecology 14(1): 1-18.
"The introduced Andropogon virginicus grass causes damage to the landscape and probably adds to the undesirable silting-up process in the Kaneohe Bay area on Oahu."

Mueller-Dombois, D. 1973c. Some Aspects of Island Ecosystems Analysis. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 19. 26 pp. Honolulu, Hawaii: University of Hawaii.
Varying degrees of impact, from mild to serious, are caused by different species of exotic grass invaders which replace native grasslands of Hawaii.

Mueller-Dombois, D. 1980. Chapter 7. The ohia dieback phenomenon in the Hawaiian rain forest, pp. 153-161, in Cairns, J., ed., The Recovery Process in Damaged Ecosystems. Ann Arbor, Michigan: Ann Arbor Science Publishers, Inc.
Trees already surviving under conditions of nutrient starvation may die from conditions of either iron toxicity or soil drought caused by varying extreme rainfall patterns.

Mueller-Dombois, D. 1981. Understanding Hawaiian forest ecosystems: the key to biological conservation, pp. 502-520, in Mueller-Dombois, D., Bridges, K.W. and H.L. Carson, eds., Island Ecosystems: Biological Organization in Selected Hawaiian Communities. 583 pp. US/IBP Synthesis Series No. 15. Stroudsburg, Pennsylvania: Hutchinson Ross Publishing Co.
A review of the complex and fragile ecosystem dynamics in the Hawaiian Islands.

Mueller-Dombois, D. 1983a. Canopy dieback and successional processes in Pacific forests. Pacific Science 37(4): 317-325.
"Massive tree (Metrosideros polymorpha) dieback has occurred periodically in the Hawaiian montane rain forest", and is a pattern and process sequence in primary succession.

Mueller-Dombois, D. 1983b. Population death in Hawaiian plant communities: a causal theory and its successional significance. Tuexenia 3: 117-130. See, also, related article in Phytocoenologia 11(1): 117-137 (1983).
Explanation of synchronized plant-group dying or dieback as a chain reaction process involving senescing cohorts and various triggering factors.

Mueller-Dombois, D. 1984a. Ohi'a Dieback in Hawaii: 1984 Synthesis and Evaluation. Hawaii Botanical Science Paper No. 45. 44 pp. Honolulu, Hawaii: University of Hawaii.
Presents new research findings, new research needs, policy and management considerations.

Mueller-Dombois, D. 1984b. Classification and mapping of plant communities: a review with emphasis on tropical vegetation, pp. 21-88, in Woodwell, G.M., ed., The Role of Terrestrial Vegetation in the Global Carbon Cycle: Measurement by Remote Sensing. John Wiley & Sons, Ltd.
Reviews methods of classifying and mapping terrestrial vegetation, with many examples from the island of Hawaii, having several main objectives including: (1) improved accuracy in estimating world phytomass, and (2) the monitoring of tropical forest loss.

Mueller-Dombois, D. 1984c. Zum Baumgruppensterben in pazifischen Inselwaldern. Phytocoenologia 12(1): 1-8.
Data on forest-stand dieback in some Pacific islands suggest it is a natural and recurring phenomenon in primary succession.

Mueller-Dombois, D. and V.J. Krajina. 1968. Comparison of east-flank vegetations on Mauna Loa and Mauna Kea, Hawaii. Proc. Symposium Recent Advances in Tropical Ecology 2: 508-520.
On Mauna Kea the cattle are interfering with the reproduction cycle of native koa, Acacia koa.

Mueller-Dombois, D. and C.H. Lamoureux. 1967. Soil - vegetation relationships in Hawaiian kipukas. Pacific Science 21(2): 286-299.
Mentions need for precise measurements of damage in pig-scarified vegetation.

Mueller-Dombois, D. and G. Spatz. 1972. The Influence of

Feral Goats on the Lowland Vegetation in Hawaii Volcanoes National Park. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 13. 46 pp. Honolulu, Hawaii: University of Hawaii. See related article, also, in Phytocoenologia 3(1): 1-29 (1975).
Impact of the grazing goats is dramatic in the coastal lowland of Hawaii Volcanoes National Park, a concentration center for feral goats.

Mull, M.E. 1975a. Comments on natural resources management plan. Elepaio 35(11): 127-131.
Concerning the goals of "re-establishing endemic plants in areas freed of destructive exotic mammals", and related matters.

Mull, M.E. 1975b. Comments on silversword planting project, Draft Environmental Assessment, June 1974 to Superintendent G. Bryan Harry, Hawaii Volcanoes National Park, from Mae E. Mull, 31 July 1974. Elepaio 36(4): 45-47.
Since the two intentionally planted forms of Argyroxiphium sandwicence did not originally occur in the Park (namely, the Haleakala silversword planted in 1953-1954, and the Mauna Kea silversword planted in 1973), it is recommended that the removal of "all existing silverswords in the Park is the only proposal consistent with the policy to re-establish rare endemic plants into their former range."

Mull, M.E. 1977. Feral sheep vs. the mamane ecosystem in the Mauna Kea Plan. Elepaio 38(5): 54-55.
Feral mammals are incompatible with native ecosystem components on Mauna Kea, Hawaii.

Mull, M.E. 1978. Question: should wild sheep be allowed to roam free on Mauna Kea? Elepaio 38(10): 117.
Presents evidence to reject, on ecological grounds, the notion of allowing sheep on Mauna Kea, Hawaii.

Mull, W.P. 1975. Magnificent minutiae. Defenders 50(6): 487-490.
Concerns insects, spiders and other creepy-crawlies of Hawaii, noting that exotic organisms cause destruction of indigenous plants and animals.

Mune, T.L. and J.W. Parham. 1956. The Declared Noxious Weeds of Fiji and Their Control. 73 pp. Bulletin No. 31. Department of Agriculture, Fiji.
Fijian weeds include prickly pear cactus, Opuntia vulgaris: "The spread of prickly pear throughout the world would never have been so extensive without the help of its greatest ally, man. These thoughtless criminals, or "cactus fans" present the biggest danger in its spread within the Colony."

Munro, G.C. 1929. Windbreaks for wind eroded lands. Hawaiian For. Agr. 26: 124-125.
Re-establishment of plant cover on denuded Lanai is discussed.

Munro, G.C. 1933. Preserving the rare plants of Hawaii. B.P. Bishop Museum Special Publication 21: 26-27.
Mentions interesting plants worth saving in various habitats.

Munro, G.C. 1952a. Revisiting the island of Lanai in 1952. Elepaio 12(10): 62-64.
Discusses status of some native rare plants, and introduced plants, as against the effects of grazing cattle, on Lanai (Hawaiian Islands).

Munro, G.C. 1952b. Attempts to save the shoreside and dryland plants of Hawaii. Elepaio 13(1): 1-5.
The earliest known attempt was made in 1918 by Harry and Frank Baldwin at Kanepuu, Hawaii, at the suggestion of Mr. Munro.

Munro, G.C. 1952c. Na Laau Hawaii. Elepaio 13(6): 39-43.
Discloses attempts to conserve areas of xerophytic or dryland forests in Hawaiian Islands made by the author, including transplanting of various species.

Munro, G.C. 1955a. Preserving the rare plants of Hawaii. Elepaio 15(10): 57-58.
Includes plea to preserve a living collection of native Lobelioideae, including Cyanea baldwinii, a species represented by only one solitary tree in nature, on Lanai. Paper originally written in 1933.

Munro, G.C. 1955b. Na Laau Hawaii. Elepaio 16(1): 1-2.
Reports on growth of Erythrina sandwicensis and other suitable dryland Hawaiian endemics introduced into a preserve.

Munro, G.C. 1957a. Na Laau Hawaii at the crossroads. Elepaio 18(5): 29-30.
Describes efforts to create and perpetuate a natural dryland area for endemic plants on the open country of Diamond Head. Several articles in successive issues of Elepaio indicate the species being grown by Mr. Munro in this sanctuary for native flora.

Munro, G.C. 1957b. Fogdrip on Lanai watershed. Elepaio 17(7): 49.
Narrative of the introduction of Norfolk Island pine (Araucaria sp.) to the wet forest of Lanai, for purposes of intercepting fogdrip to recharge ground water.

Munro, G.C. 1970. Axis deer on Molokai and Lanai, circa 1952. Elepaio 31(2): 15-17.
"It was partly on my suggestion that deer were taken to Lanai. I class that as the greatest mistake I made on that island."

Murdock, G.P. 1963. Human influences on the ecosystems of high islands of the tropical Pacific, pp. 145-154, in Fosberg, F.R., ed. (1963).
Notes some examples of degree of man's influence on Pacific vegetation.

Murthy, S.G. 1985. Sandalwood: case study of a resource decline. Garden 9(1): 16-19.
Article concerns the decline of the tree in India, which is interesting to compare with the erstwhile sandalwood trade in Oceania.

Muzik, K. 1985. Dying coral reefs of the Ryukyu Archipelago (Japan). Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 256. (Abstract)
"Natural vegetation (of Okinawa Prefecture) has been extensively removed, for dams and pineapple fields. Riverbanks and shorelines have been paved with cement, leading to extreme loss of topsoil with every rainfall."

Myers, N. 1980. Conversion of Tropical Moist Forests. Washington, D.C.: U.S. National Academy of Sciences.
Includes statistics of forest-felling in Melanesia.

Myrhe, S.B. 1970. Kahoolawe. Newsletter Hawaiian Botanical Society 9(4): 21-27.
Details the effects of introduced animals and plants on the indigenous vegetation of Kahoolawe, Hawaiian Islands.

Nagata, K. 1971. Hawaiian medicinal plants. Economic Botany 25(3): 245-254.
Describes uses made by traditional medical practitioners of Hawaiian healing.

Nagata, K. 1981. Unpublished manuscript. Status report on Achyranthes rotundata (Hdb.) St.John (Amaranthaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Nagata, K. 1982. Unpublished manuscript. Status report on Isodendrion hosakae St.John (Violaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Nanyo Cho (South Seas Government). 1932. Nanyo Gunto Shashin Chyo (Photo Album of the South Sea Islands). 90 pp. Palau.

Photos of Micronesian vegetation, useful for determining changes due to World War II military operations on various islands. At Library of Congress, Washington, D.C. (Orientalia, Japan).

Nelson, R.E. 1960. Silk-oak in Hawaii: Pest or Potential Timber? 5 pp. Pacific Southwest Forest and Range Experiment Station, Miscellaneous Paper No. 47.
Grevillea robusta from Australia is much planted by watershed managers in Hawaii for soil stabilization, but it is a vigorous, natural self-seeder which poses a threat to some grazing lands.

Nelson, R.E. 1964. A Look at the Forests of American Samoa. 14 pp. U.S. Forest Service, Research Note PSW-53.
Includes recommendations that watershed values in Samoan forested mountains must be protected and enhanced, and that the possible consequences of expanded agricultural activities should be carefully studied.

Nelson, R.E. 1967. Records and Maps of Forest Types in Hawaii. 22 pp. U.S. Forest Service Resource Bulletin PSW-8.
Includes discussion of Hawaiian vegetation changes after the year 1788 due to timber harvesting, animals and insects, fire, and plant introductions.

Nelson, R.E. 1971. Hawaii's forest resource needs, production potentials, and constraints. Proc. Twelfth Pacific Science Congress 1:118. (Abstract)
Constraints to developing the productive capacity of forest-land to grow exotic timber crops in Hawaii include the watershed value of unlogged forests and the preservation of native forests as natural ecosystems.

Nelson, R.E. and E.M. Hornibrook. 1962. Commercial Uses and Volume of Hawaiian Tree Fern. 10 pp. Pacific Southwest Forest and Range Experiment Station, Technical Paper 73.
The Hawaiian tree ferns, 3 species of Cibotium (Dicksoniaceae), are now on Appendix II of CITES and international trade in their parts and derivatives is monitored.

Newell, L.A. 1986. Demographics and mangrove resources in the Eastern Carolines. American Pacific Forestry News July 1986: 5-7.
Discussion of presumed cumulative impact of economic activities on the mangrove forests of Moen (Truk Lagoon) and Pohnpei. "The pressures on Pohnpei's mangroves come from settlement, logging for sawtimber, cutting for fuelwood and craftwood, siltation from roadbuilding, dredging, and disturbance of upland forests."

Newhouse, J. 1979. The energy budget of Takapoto, Tuamotu Archipelago, 1976. Cahiers de l'Indo-Pacifique 1(2): 195-213.

The tight energy budget on Takapoto is contravened by any act of plant resource exploitation within the vulnerable ecosystems, including the replacement of indigenous flora by coconut plantations.

Newhouse, J. 1980. Marine and terrestrial flora of atolls. C.R. Soc. Biogeographie 491: 63-68.

Includes remarks on introduced floras of Pacific atoll runways, where it is suspected that "a number of these plants arrived as seeds caught in the external seams of airplanes."

Nicholson, E.M. 1969. Draft check list of Pacific oceanic islands. Micronesica 5(2): 327-463.

Includes information on past and present land use, as well as status and scientific knowledge, of each Pacific island group.

Nicholson, E.M. and G.L. Douglas. 1970. Conservation of oceanic islands, pp. 200-211, in IUCN Publications New Series, No. 17. IUCN Eleventh Technical Meeting, New Delhi 1969, Vol. I.

Includes recommendations for the conservation of Palau Islands National Park, Bonin Is., Ryukyu Is., and Hawaiian wildlife reserve areas.

Nicholson, E.M. and L.C. Eldredge, eds. 1970. International Biological Programme Technical Meeting on Conservation of Pacific Islands held at Koror, Palau and Guam in November, 1968. Proceedings. Micronesica 5(2): 1-496.

Relevant articles are separately cited.

Niering, W.A. 1956. Bioecology of Kapingamarangi Atoll, Caroline Islands: Terrestrial Aspects. 32 pp. + 33 figs. SIM Report No. 22. Washington, D.C.: Pacific Science Board, National Research Council.

Calophyllum inophyllum trees, whose wood is in high demand for making saleable coconut grater handicrafts, are disappearing from the lagoon shore faster than they are being replaced.

Niering, W.A. 1961. Observations on Puluwat and Gaferut, Caroline Islands; with historical and climatic information on Gaferut Island by M.-H. Sachet. Atoll Research Bulletin 76: 1-15.

Includes description of Gaferut vegetation and speculation on the history of its alteration.

Niering, W.A. 1963. Terrestrial ecology of Kapingamarangi Atoll, Caroline Islands. Ecological Monographs 33: 131-

160.
Man's impact on the vegetation includes selective clearing of the native undergrowth since many of the species are used in construction and in making utensils and handicrafts.

Nisbet, I.C.T. 1976. Pacific follies, or the ravishing of Hawaii. Technology Review 78: 8-9.
Environmental alterations negatively affecting the Hawaiian Islands are discussed.

Nishi, M. 1968. An evaluation of Japanese agricultural and fishery developments in Micronesia during the Japanese Mandate 1914 to 1941. Micronesica 4(1): 1-18.
"A total of 238 fruits, vegetables, grasses, shrubs, and trees not previously found in the Islands were experimentally attempted for their agricultural promise."

Nolan, R.S., McConnaughey, R.R. and C.R. Stearns. 1975. Fishes inhabiting two small nuclear test craters at Enewetak Atoll, Marshall Islands. Micronesica 11(2): 205-217.
Instructive for the visualization of landscape demolishment, showing aerial photos of two "small" (354 feet, or 118 meters, in diameter) nuclear test craters on Runit (Yvonne) Island: Cactus Crater created by detonation May 1958, and LaCrosse Crater created by detonation April 1956.

Norris, R. 1986. The last interstate battle. Audubon 88(6): 46, 48-51.
Expresses concern for potential environmental damage which could be caused by construction of Interstate Highway H-3, connecting Kaneohe with Pearl Harbor, on Oahu, Hawaiian Islands.

Numata, M. 1969. Ecological background and conservation of Japanese islands. Micronesica 5(2): 295-302.
Discussion topics include the remarkably thorough disfigurement of the Bonin and Ryukyu island ecosystems by human activities.

Obata, J. 1976. Cultivating an "extinct" species. Newsletter Hawaiian Botanical Society 15(2): 35-37.
Tetramolopium filiforme (Compositae) rediscovered on Oahu.

Obata, J.K. 1985a. Another noxious melastome? *Oxyspora paniculata*. Newsletter Hawaiian Botanical Society 24: 25-26.
A large, regenerating population of *O. paniculata* on Oahu, along the upper Lulumahu Stream, seems to be displacing yet another noxious melastome, the Koster's

curse (Clidemia hirta).

Obata, J.K. 1985b. The declining forest cover of the Ko'olau summit. Newsletter Hawaiian Botanical Society 24: 41-42.
The changing, exotic vegetation lacks the fog interception capabilities of the stable, native Metrosideros tree cover.

Obata, J.K. 1986. The demise of a species: Urera kaalae. Newsletter Hawaiian Botanical Society 25(2): 74-75.
This species is relegated to the talus slopes in the Kunia Mts. of Oahu, Hawaiian Islands, where threatening weeds in its habitat include Passiflora, Schinus, and Psidium.

Obata, J.K. and C.W. Smith. Undated, unpublished manuscript. Status report on Cyanea superba (Cham.)Gray (Campanulaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Oberhansley, F.R. 1953. Some conservation problems in Hawaii National Park. Proc. Seventh Pacific Science Congress 4: 652-657.
Compares feral goats in the park to "hoofed locusts", noting also that when the park was established it inherited a problem: "Unplanned development of roads, trails, and structures designed for human convenience with little thought given to the preservation of the primeval wilderness resulted in unrestricted encroachment on the most vital parts of the area."

Office of the Chief Engineer, General Headquarters, Army Forces, Pacific. 1951. Engineers of the Southwest Pacific 1941-1945. Volume VI: Airfield and Base Development. 533 pp. Southwest Pacific Area Army Forces, Pacific.
In the Southwest Pacific Theater of Operations during World War II, vegetation clearance for airfields was necessary. On Norfolk Island, 350 giant pines had to be removed from the airfield site. On Woodlark Island, more than 10,000 feet of over-all clearing was required to obtain the desired maximum glide angle for the aircraft. For construction of Mokerang airdrome on Los Negros Island (Admiralty Is.), "the work consisted of clearing 1,100 acres, from which 18,000 coconut trees were removed, stripping 360,000 cubic yards of overburden, moving 172,000 cubic yards of coral in preparing the subgrade and surfacing." In general, "Clearing of airfield sites in the Southwest Pacific ranged from the comparatively simple mowing of thick kunai grass to the removal of extensive and heavy rain forests. Width of necessary clearing depended upon a number of factors, including height of trees and local conditions, such as

cross winds, obstructions, and direction of runway in regard to prevailing winds."

Okutomi, H., *et al.* 1982. Endemic flora and fauna, pp. 393-403, in Okutomi, H., ed., *Conservation Reports of the Minami-Iwojima Wilderness Area.* 403 pp. Tokyo, Japan: Nature Conservation Bureau, Environment Agency of Japan.
Concerns Volcano Island.

Oliver, D.L. 1951. *Planning Micronesia's Future.* 94 pp. Cambridge, Massachusetts: Harvard University Press.
Recognises that biological conservation programs should be instituted.

Ono, M. 1985. Speciation and distribution of *Pittosporum* in the Bonin Islands, pp. 7-17, in Hara, H., ed., *Origin and Evolution of Diversity in Plants and Plant Communities.* Tokyo, Japan: Academic Scientific Book Inc.
Includes notes on the endangered *Pittosporum parvifolium* of Chichijima, Bonin Islands.

Ono, M., Kobayashi, S. and N. Kawakubo. 1986. Present situation of endangered plant species in the Bonin (Ogasawara) Islands. *Ogasawara Research* 12: 1-32.
A brief discussion of the history of the Bonin Islands is followed by a list of endangered plant species, with special attention given to some of the most critically endangered ones. Several causes of their precarious situation are discussed.

Ord, W.M. 1962. Preservation of plants and wildlife in Hawaii. *Elepaio* 22(10): 75-77.
Mourns the loss of the 1940 open hunting season for shooting feral animals.

Otobed, D.O. 1975. Conservation priorities in Micronesia, pp. 73-79, in Force, R.W. and B. Bishop, eds., *The Impact of Urban Centers in the Pacific.* 362 pp. Honolulu, Hawaii: Pacific Science Association.
Recognises importance of indigenous flora as a basic island resource.

Owen, R.P. 1978. Conservation is for everyone. *Micronesian Reporter* 26(3): 16-20.
The Rock Island Palm (*Gulubia palauensis*) is an endangered species which is attacked in Palau by the sulphur-crested cockatoo, an introduced bird which chews through the crownshaft and topples it.

Owen, R.P. 1979. A conservation program for the Trust Territory. *Micronesian Reporter* 27(1): 22-28.
Recognises the ecological importance of plant species and asks for the creation of wildlife preserves and national parks.

Pacific Ocean Biological Survey Program. 1964. Preliminary Biological Survey of Sand Island - Johnston Atoll. 136 pp. Washington, D.C.: Smithsonian Institution.
"The role of man as an agent in plant introduction on Sand-Johnston Atoll is emphasized by the fact that the man-created portion of Sand has almost twice the plant variety that the original portion has."

Pacific Science Board. 1953. Our Heritage in the Pacific. 13 pp. Washington, D.C.: Pacific Science Board of the National Academy of Sciences - National Research Council.
Unique document for sensing the immediacy of post-war concerns for the conservation of Pacific flora, forests and fauna for all humanity.

Paine, R.W. 1934. The control of Koster's curse (Clidemia hirta) on Tavenui. Agriculture Journal (Fiji) 7(1): 10-21.
Results of experiments designed to exterminate a noxious weed on a Fijian island.

Palumbo, R.F. 1962. Recovery of the land plants at Eniwetok Atoll following a nuclear detonation. Radiation Botany 1(2): 182-189.
All plants except a few species (Guettarda, Lepturus, Portulaca spp.) recovered rapidly.

Paramonov, S.J. 1963. Lord Howe Island, a riddle of the Pacific, Part III. Pacific Science 17(3): 361-373.
Discusses composition of native flora. Interesting for the map of the island bearing different symbols indicating "wild goats" and "wild pigs" placed where those animals are concentrated.

Pardo, R. 1984. Forestry and "customary land ownership": are they compatible? American Forests 90(10): 41, 60-62.
Includes notes on Pinus caribaea in Fiji.

Parham, B.E.V. 1953a. The naturalized flora of Fiji, with special reference to the grasses, legumes and weeds. Proc. Seventh Pacific Science Congress 5: 221-253.
There are many exotic induced plant communities in Fiji. Recognition of the increasing economic importance of the exotic vegetation may lead to the more detailed long-term investigations which are necessary to any future plan to combat the further degradation of natural resources.

Parham, B.E.V. 1953b. International Technical Conference on the Protection of Nature - 1949. The Fiji Society 4: 54-56.
In Fiji, some attention should be given to the protection of the native banana (Musa fehi) and the

beautiful indigenous shrub *Lindenia vitiensis*, both of which are very rare at the present time.

Parham, B.E.V. 1953c. Recent advances in local weed control. *Transactions and Proceedings, Fiji Society of Science and Industry* 3(3): 160-165.
Weeds are "partners (with man) in the crime of converting the valuable lands of the (Fiji) Colony into unproductive wastes."

Parham, B.E.V. 1953d. Notes on the alien flora of Fiji, or the effect of settlement upon the vegetation of Fiji. *Fiji Society of Science and Industry* 2(2): 76-88.
Includes many plants originally introduced for ornamental purposes.

Parman, T. 1975. An autecological review of *Sophora chrysophylla* in Hawaii. *Newsletter Hawaiian Botanical Society* 14(3): 40-49.
"Both habitat manipulation (e.g. land clearing, planting exotic species) and habitat destruction by exotic feral mammals have been important factors in the decline of this endemic tree."

Parrat, J. 1971. Destruction et defense de la couverture vegetale en Nouvelle-Caledonie, pp. 1-6, in *Colloque Regional sur la Protection de la Nature - Recifs et Lagons*, Commission du Pacific Sud (Noumea, 1971). SPC/RSCN/WP 16 (597/71). Reviewed by Plessis, J. 1972. *Cahiers du Pacifique* 16: 214.
A special problem of New Caledonian vegetation conservation is the ever-increasing effects of mining and attendant pollution. Reclamation of butchered terrain and protection of forests containing rare endemic species are encouraged.

Parsons, J. 1945. Coffee and settlement in New Caledonia. *Geographical Review* 35(1): 12-21.
Introduced, aggressive flora of the expanding brush community includes guava, lantana, *Leucaena glauca*, *Acacia spirorbis*, and *Acacia farnesiana*.

Patterson, C.B. 1986. At the birth of nations. *National Geographic* 170(4): 460-499.
Includes depiction of the garbage-encrusted coastal environment of Ebeye in the Marshall Islands. Elsewhere in the Marshalls, it is noted that "Kwajalein is the Pacific terminus (target) of a U.S. missile range, where experts measure the splashdown accuracy of ballistic rockets fired from Vandenberg Air Force Base, 4,500 miles away in California. The facility is expected to play an important part should President Reagan's "Star Wars" technology go forward."

Perez, G.S.A. 1975. Guam conservation priorities, pp. 89-96, in Force, R.W. and B. Bishop, eds., The Impact of Urban Centers in the Pacific. 362 pp. Honolulu, Hawaii: Pacific Science Association.
Notes that tourism and the geographic-strategic importance of Guam, combined with continued population pressures, presents a conservation dilemma characterized by depletion of marine resources, soil erosion, disappearance of plant and animal life, pollution, and socio-economic dislocation.

Perlman, S. 1977. Collecting breadfruit in the Society Islands. Bulletin Pacific Tropical Botanical Garden 7(4): 81-84.
Rare and disappearing variants such as the Tahitian lavender-fruited "Afara" variety of breadfruit, and seeds of the endangered Erythrina tahitensis from the last tree on Mt. Aori, were collected.

Perlman, S. 1978. A rare Hawaiian orchid. Bulletin Pacific Tropical Botanical Garden 8(1): 19.
Eight plants of Platanthera holochila were discovered in Alakai Swamp bog, Mt. Waialeale, Kauai.

Perlman, S.P. 1979. Brighamia in Hawaii. Bulletin Pacific Tropical Botanical Garden 9(1): 1-2.
All species of Brighamia (Lobeliaceae) are rare and endangered. B. citrina var. napaliensis from Kauai was collected for cultivation.

Perry, L.M. and J. Metzger. 1980. Medicinal Plants of East and Southeast Asia. 620 pp. Cambridge, Massachusetts and London, England: MIT Press.
Coverage includes the Solomon Islands.

Perry, R. 1969. Conservation problems in the Galapagos Islands. Micronesica 5(2): 275-281.
"Grazing by introduced animals is leading toward the local extermination of certain (indigenous) plants, such as Opuntia, upon which the tortoises rely almost exclusively for food during the dry seasons."

Perry, R. 1974. Sunflower trees of the Galapagos. Noticias de Galapagos 22: 11-13.
On Santa Cruz, both the endemic Miconia robinsoniana and Scalesia pedunculata (sunflower tree) have largely disappeared as a result of land clearance, grazing by domestic animals and burning.

Perry, R. 1984a. Juan Fernandez Islands: a unique botanical heritage. Environmental Conservation 11(1): 72-76.
Discusses interesting endemic plant species.

Perry, R. 1984b. Galapagos. Key Environment Series. 321 pp. Oxford, England: IUCN/Pergamon Press.
In-depth coverage of Galapagos ecosystems.

Petard, P. 1948. La vegetation madreporique du District de Teavaro (Ile Moorea). Journal Soc. Oceanistes 4:115-131.
The character of the indigenous Tahitian vegetation near the large European establishments has been completely stamped out.

Peterson, B. 1964. Carl Skottsberg, 1880-1963. Taxon 13(1): 1-7.
Succinct description of Skottsberg's interest in the vulnerable vegetation of Juan Fernandez Is. and his influence in establishing the national park.

Peterson, D. 1976. The Scientific Report of the Manawainui Research Project, East Maui, Hawaii. 320 pp. National Science Foundation. Unpublished report.
Includes considerations of harmful feral pigs and other threats to the vegetation.

Peterson, R.T. 1967. The Galapagos: eerie cradle of new species. National Geographic 131(4): 541-585.
General background on Galapagos ecosystems.

Pickard, J. 1973. An annotated botanical bibliography of Lord Howe Island. Contributions from New South Wales National Herbarium 4: 470-491.
Includes many articles of phytogeographic interest.

Pickard, J. 1980. The palm seed industry on Lord Howe Island. Principes 24(1): 3-13.
Seeds of four endemic species are harvested: Howea forsterana (Kentia palm), Howea belmoreana (Curly palm), Hedyscepe canterburyana (Big Mountain palm), and Lepidorrhachis mooreana (Small Mountain palm). Seed production is threatened by the overabundance of rats which damage this crop.

Pickard, J. 1984. Exotic plants on Lord Howe Island: distribution in space and time, 1853-1981. Journal of Biogeography 11(3): 181.
Influence of introduced flora on native species.

Pickford, G.D. 1962. Opportunities for Timber Production in Hawaii. 11 pp. Pacific Southwest Forest and Range Experiment Station, Miscellaneous Paper No. 67.
The author observes that, on the relatively idle acreage of Hawaii state forest reserves, "some exotic timber species are far more suitable and compatible to recreation use than is the present jungle type."

Polansky, E.A. 1966. Rabaul. South Pacific Bulletin 16(2):

42-47.
Notes regarding Rabaul, located on the Gazelle Peninsula of New Britain, "During the war years until 1945, Allied bombing obliterated the old town with its famous Botanical Gardens."

Porcher, M. and M. Dupuy. 1985. Environment and coastal land use planning in coral reef areas, French Polynesia. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 303. (Abstract)
Includes coastal zone management scheme, and studies of micro-areas for precise impact studies, especially of tourism projects near the lagoon.

Porteous, J.D. 1978. Easter Island: the Scottish connection. Geographical Review 68(2): 145-156.
The mode of exploitation during the past 100 years has been directed by the enterprise of two successive Scottish sheep-rearing companies. The role of the companies in the transformation of Easter Island is considered in terms of sociopolitical structure, economy, and landscape.

Porter, D.M. 1976. Geography and dispersal of Galapagos Islands vascular plants. Nature 264 (5588): 745-746.
The deleterious effects on the native flora of some of the species introduced by man (which total 124 weed and 57 cultivated exotic species) are just beginning to be appreciated.

Porter, D.M. 1979. Endemism and evolution in Galapagos Islands vascular plants, pp. 225-256, in Bramwell, D., ed., Plants and Islands. London and New York: Academic Press.
Much useful background data on indigenous flora.

Powell, E. 1982. Unpublished manuscript. Status report on Santalum ellipticum var. littorale (Hdb.) Skottsberg (Santalaceae). Washington, D.C.: Department of the Interior.
Endangered plants of Hawaiian Islands.

Powell, E. 1985. The Mauna Kea silversword: a species on the brink of extinction. Newsletter Hawaiian Botanical Society 24: 44-57.
Concerns Argyroxiphium sandwicense (Compositae), which is not regenerating naturally, and is further threatened by mouflon sheep.

Powell, R.H. 1968. Harmful plant species entering New Zealand 1963-1967. New Zealand Journal of Botany 6(3): 395-402.
Hawaii and Fiji are probable sources of some potentially harmful species arriving in New Zealand.

Pratt, T. 1973. Plant communities and bird distribution on East Molokai. Elepaio 33(7): 66-70.
Chronicles extensive damage by feral goats and cattle, noting that "surely Molokai must lose more forest every year to these two animals than is reclaimed by reforestation with Eucalyptus and pines."

Prescott-Allen, R. and C. Prescott-Allen. 1982. The case for in situ conservation of crop genetic resources. Nature and Resources 18(1): 15-20.
Lycopersicon cheesmanii , a wild relative of the tomato from Galapagos, has maritime ecotypes that are tolerant of saline soils, which should be autecologically studied in situ.

Price, W. 1936. Mysterious Micronesia: Japan's mandated islands. National Geographic 69(4): 481-510.
Notes that 238 plant species have been introduced into the Marianas by the Japanese. See, also, similar article by same author, op. cit. 81(6): 759-785(1942).

Prior, I. and J. Stanhope. 1980. Epidemics, health and disease in a small, isolated environment. World Development 8: 995-1016.
"Some health consequences of the interaction of man and his environment on the three small Pacific atolls that constitute Tokelau are examined."

Pulea, M. 1984. Environmental legislation in the Pacific region. Ambio 13(5-6): 369-371.
Refers to Tonga.

Pung, E. 1971. Forestry saves koai'a. Aloha Aina 2(2): 25-26.
The endangered endemic koai'a tree (Acacia koaia) on Hawaii was over-browsed by cows nearly to the point of total destruction, before the Koai'a Sanctuary was designated in 1950. Trees are regenerating.

Radovsky, F. J., Raven, P.H., and S.H. Sohmer, eds. 1984. Biogeography of the Tropical Pacific. 221 pp. B.P. Bishop Museum Special Publication No. 72.
Proceedings of a symposium, including articles on endemism and extinctions.

Rageau, J. 1973. Les Plantes Medicinales de la Nouvelle-Caledonie. 139 pp. Travaux et Documents de ORSTOM, No. 23.
Most of the endemic plants (80 percent of the New Caledonian flora) await biochemical and pharmacodynamic investigation. This document reviews medicinal properties of 600 mostly introduced species.

Ralph, C.J. 1978. Hawaiian plant on endangered species

list. _Elepaio_ 38(12): 142-143.
Refers to _Vicia menziesii_ (Leguminosae).

Ralph, C.J. 1982. Birds of the forest. _Natural History_ 91(12): 40-45.
In the Hawaiian Islands, deforestation has caused severe reduction in habitat of many indigenous forest birds, affecting biological diversity of the region. Logging of koa trees is particularly disastrous.

Ralph, C.J., Pearson, A.P., and D.C. Phillips. 1980. Observations on the life history of the endangered Hawaiian vetch (_Vicia menziesii_) (Fabaceae) and its use by birds. _Pacific Science_ 34(2): 83-92.
"Our study shows that the species appears to be susceptible to herbivore damage and suggests that this is probably the major limiting factor in its present limited distribution."

Randall, J.E. 1973. Expedition to Pitcairn. _Oceans_ 6(2): 12-21.
Wood of _Thespesia_ is utterly depleted on Pitcairn Island.

Randall, R.H. and J. Holloman. 1974. _Coastal Survey of Guam._ 404 pp. University of Guam Marine Laboratory, Technical Report No. 14.
Contains remarks on status of Guam vegetation from Fosberg, F.R. in Tracey, J.I., _et al._ (1959).

Randall, R.H. and R.T. Tsuda. 1974. _Field Ecological Survey of the Agana - Chaot River Basin._ 64 pp. University of Guam Marine Laboratory, Technical Report No. 12.
Sensitivity of the Agana, Guam marsh and swampland environment to activities of man, such as the influence of dredging and land-filling on the water table, are discussed.

Ranjitsinh, M.K. 1979. Forest destruction in Asia and the South Pacific. _Ambio_ 8(5): 192-201.
Contains a minimum of information regarding South Pacific islands.

Rao, Y.S. and C. Chandrasekharan. 1983. The state of forestry in Asia and the Pacific. _Unasylva_ 35(140): 11-21.
Includes considerations of deforestation.

Rappaport, R.A. 1963. Aspects of man's influence upon island ecosystems: alteration and control, pp. 155-174, in Fosberg, F.R., ed. (1963).
Elements introduced in pre-European times by the founding indigenous Pacific peoples are discussed in detail, including examples of introductions and elimina-

tions of plants.

Rauh, W. 1981. Brighamia insignis, a curious succulent of the lobelia family, from the Hawaiian Islands. Cactus and Succulent Journal (U.S.) 53(5): 219-220.
A rare endemic plant species.

Raynal, J. 1979. Three examples of endangered nature in the Pacific Ocean, pp. 149-150, in Hedberg, I., ed., Systematic Botany, Plant Utilization and Biosphere Conservation. Stockholm, Sweden: Almqvist & Wiksell International.
Endangered ecosystems in the Society Is., New Hebrides, and New Caledonia are discussed.

Reboul, J.L. 1975. Deux exemples d'introductions malheureuses pour la nature polynesienne. Te Natura o Polynesia 2: 14-20.
Concerns the ravages of the water hyacinth, Eichornia crassipes, in Tahiti and neighboring islands.

Reed, E.K. 1952. General Report on Archaeology and History of Guam. 133 pp. Washington, D.C.: National Park Service.
Includes general notes on extensive vegetation changes on Guam due to land clearance and annual burning of hilly grasslands.

Reeser, D.W. 1976. Successful goat control at Hawaii Volcanoes. Parks 1(2): 14-15.
This National Park in Hawaii began a fencing program to curtail the devastating effects of feral goats (Capra hircus), and the vegetation has responded by regenerating within the fenced areas.

Richardson, F. 1949. The status of native land birds on Molokai, Hawaiian Islands. Pacific Science 3(3): 226-230.
"Pigs, deer and cattle apparently do not now occur in Pelekunu and Wailau Valleys, but once in these valleys it seems apparent that they would work their way up the least precipitous slopes and irreparably alter the native forest."

Richardson, F. 1963. Birds of Lehua Island off Niihau, Hawaii. Elepaio 23(9): 43-45.
Advises the eradication of vegetation-damaging rabbits from the island.

Richmond, G.B. 1965. Naturalization of Java podocarpus in Hawaii rain forest. 5 pp. U.S. Forest Service Research Note PSW-76. Pacific Southwest Forest and Range Experiment Station, Berkeley, California.
Podocarpus cupressina is naturalized in rainforest near Hilo, Hawaii, where reproduction has invaded both planted forest and undisturbed native forest.

Ridgeway, J. 1983. Micronesia: America's Third World. Amicus Journal 5(2): 16-25.
Suggests that Micronesia is the "Siberia" of the United States, "poised on the edge of potentially devastating economic exploitation", and subjected to hopelessly incompetent planning on some of the islands.

Rinke, D. 1986. The status of wildlife in Tonga. Oryx 20: 146-151.
Human encroachment upon available habitat for wildlife decimates the plant cover of the island.

Robbins, R.G. 1972. Vegetation and man in the Southwest Pacific and New Guinea, in Ward, R.G., ed., Man in the Pacific Islands; Essays on Geographical Change in the Pacific Islands. 339 pp. Oxford, England.

Robyns, W. and S.H. Lamb. 1939. Preliminary ecological survey of the island of Hawaii. Bull. Jardin Botanique Bruxelles 15(3): 241-293.
The progress of natural plant succession is impeded or obscured by overgrazing, and by the establishment of new climaxes by introduced, aggressive grasses, shrubs, and trees.

Rock, J.F. 1916. The Sandalwoods of Hawaii. 43 pp. Botanical Bulletin No. 3. Territory of Hawaii, Board of Agriculture and Forestry.
Includes history of depletion of Hawaiian groves of fragrant sandalwood.

Roedelberger, F.A. and V.I. Groschoff. 1967. Wildlife of the South Seas. 216 pp. London: Constable; New York: Viking Press.
On Pacific islands, "goats, rabbits and pigs ruined the restricted vegetation and deprive the indigenous (bird) species of their food." Book review appears in Special Supplement to IUCN Bulletin 2(11): 7 (1976).

Rogers, D. 1975. Micronesian Claims Commission: its origin and goals. Micronesian Reporter 23(2): 8-12.
Claims brought by Micronesians due to land used and destroyed for agricultural purposes by U.S. Forces, in the Pacific Theater of Operations during World War II, will receive an award of $90 to $1,500 per acre. Claims due to death by starvation will receive an initial payment of up to $1,000. Includes photos of devastated landscapes.

Ronck, R. 1975. New world in the Marianas. Oceans 8(6): 6-9.
Notes a record for Cordia on Maug I.

Root, I.C. 1952. Report on Park and Recreation Areas, Territory of Guam. 67 pp. Washington, D.C.: National Park Service.
Observes that "The island of Guam at one time was densely forested. The Japanese occupation reduced the already depleted timber land and post-war construction has taken all of the remaining timber of usable size that is readily accessible."

Routley, R. and V. Routley. 1980. Destructive forestry in Melanesia and Australia. Ecologist 10(1-2): 56-67.
Deforestation poses a serious problem on some Melanesian islands.

Russ, G.W. 1932. Notes on the distribution of Neowawrea. B.P. Bishop Museum Special Publication 20: 6-7.
N. phyllanthoides (Euphorbiaceae) has been virtually exterminated in the Hawaiian Is. due to vegetational changes.

Sabath, M.D. 1977. Vegetation and urbanization on Majuro Atoll, Marshall Islands. Pacific Science 31(4): 321-333.
Urbanization on Uliga, Dalap and Djarrit since 1944 resulted in reduction of tree canopy; establishment of extensive yards with grasses and herbs; and reduction of many indigenous and aboriginally introduced understory species.

Sablan, M.C. 1976. Anatahan. Micronesian Reporter 23(1): 37-38.
On Anatahan (Marianas), no Leucaena glauca was observed, but the number of goats on this uninhabited island is "staggering".

Sachet, M.-H. 1954. A summary of information on Rose Atoll. Atoll Research Bulletin 29: 1-25.
Includes an urgent plea for conservation of this unoccupied atoll of eastern Samoa.

Sachet, M.-H. 1957. The vegetation of Melanesia: a summary of the literature. Proc. Eighth Pacific Science Congress 4: 35-47.
The post-World War II status of Eucalyptus naudiniana lowland forest on New Britain is questionable, as these trees which attain heights of up to 240 feet were being actively logged even in the 1920's. Article discusses northwest Melanesia, New Hebrides, New Caledonia.

Sachet, M.-H. 1963. History of change in the biota of Clipperton Island, pp. 525-534, in Gressitt, J.L., ed. (1963).
Influence of introduced pigs and weeds on the original vegetation is discussed.

Sachet, M.-H. 1973. The discovery of Lebronnecia kokioides. Bull. Pacific Tropical Botanical Garden 3(3): 41-43.
Rare malvaceous species from the Marquesas (Tahuata I.), with seeds covered with long, brown hair as in a wild cotton.

Sachet, M.-H. 1983a. Vegetation et flore terrestre de l'atoll de Scilly (Fenua Ura). Journal Societe Oceanistes 39(77): 29-34.
Coconut plantations have replaced much of the natural plant cover of this atoll in French Polynesia.

Sachet, M.-H. 1983b. Takapoto Atoll, Tuamotu Archipelago: terrestrial vegetation and flora. Atoll Research Bulletin 277: 1-41.
"With the coming of European man, much of the forest was destroyed and replaced by coconut groves or plantations."

Sachet, M.-H. 1983c. Botanique de l'ile de Tupai, Iles de la Societe. Atoll Research Bulletin 276: 1-26.
Essentially the atoll of Tupai has been transformed into a coconut plantation.

Sachet, M.-H. 1983d. Natural history of Mopelia Atoll, Society Islands. Atoll Research Bulletin 274: 1-37.
"The overriding characteristic of the vegetation of Mopelia is that most of it, especially inland, is very profoundly disturbed, coconut palms having been planted everywhere."

Sachet, M.-H. and F.R. Fosberg. 1983. An ecological reconnaisance of Tetiaroa Atoll, Society Islands. Atoll Research Bulletin 275: 1-67.
Published with the accord of the owner of Tetiaroa Atoll, Mr. Marlon Brando, this article suggests environmentally sound procedures regarding human activities, ecological objectives, management, and future development of the atoll, comprising 13 vegetated islets which have been profoundly altered by both Polynesian inhabitants and European copra producers.

Sachet, M.-H., Schafer, P.A., and J.C. Thibault. 1975. Mohotani: une ile protegee aux Marquises. Bull. Soc. Etudes Oceaniennes 16(6) (No. 193): 557-568.
The action of man on the vegetation through the introduction of sheep, is discussed.

Sakagami, S.F. 1961. An ecological perspective of Marcus Island, with special reference to land animals. Pacific Science 15(1): 82-104.
Marcus Island received 171 attacks from 759 bombers from September 1944 to the Armistice on August 15, 1945. "All

trees on the island were completely damaged by repeated bombing during the war. The present arboreal stratum is, therefore, the outcome of postwar regeneration."

Salcedo, C. 1970. The search for medicinal plants in Micronesia. Micronesian Reporter 18(3): 10-17.
Describes efforts on Palau to learn the uses of plants employed by traditional medical practitioners, which are often kept secret, as groundwork for possible development of new medicines and the income they will produce.

Salvat, B. 1976. Un programme interdisciplinaire sur les ecosystemes insulaires en Polynesie francaise. Cahiers Pacifique 19: 397-405.
Development of island ecosystem studies in French Polynesia is discussed.

Salvat, B. 1985. An integrated (geomorphological and economical) classification of French Polynesian atolls. Proc. Fifth International Coral Reef Congress (Tahiti, 1985): 2: 337. (Abstract)
The economic classification includes consideration of resource exploitation.

Salvat, B. and G. Richard. 1985. Takapoto Atoll, Tuamotu Archipelago. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 1: 323-377.
"Before its destruction and replacement by coconut plantations, clearly marked due to brush cutting and burning activities, much of Takapoto's emerged land mass was probably covered by forest (scrub vegetation, as too were many atolls of the region.)"

Sampson, P. 1968. The Bonins and Iwo Jima go back to Japan. National Geographic 134(1): 128-144.
The islands have developed infestations of Leucaena, originally planted as camouflage during World War II.

Sanders, R.W., Stuessey, T.F. and C. Marticorena. 1982. Recent changes in the flora of the Juan Fernandez Islands, Chile. Taxon 31(2): 284-289.
Vegetation of the islands has been impacted by human activities.

Schafer, P.A. 1977. La Vegetation et l'Influence Humaine aux Iles Marquises. 31 pp. Montpellier, France: Academie de Montpellier, Universite des Sciences et Techniques du Languedoc.
The profoundly detrimental effects of human intervention in the vegetation of the Marquesas are discussed and illustrated.

Scheuer, P.J. 1961. Natural products from Hawaiian plants. Proc. Hawaiian Academy of Science 36(1960-1961): 18.

Discusses chemical constituents of species of _Ochrosia_, _Platydesma_, _Pelea_, _Tacca_, _Piper_, _Eugenia_ and _Passiflora_.

Schlanger, S.O. and G.W. Gillett. 1976. A geological perspective of the upland biota of Laysan Atoll (Hawaiian Islands). _Biological Journal of the Linnean Society_ 8(3): 205-216.
"Laysan is viewed as a refugium for upland and montane lineages able to keep pace, via great adaptive flexibility, with drastic habitat changes."

Schmid, M. 1981. _Fleurs et Plantes de Nouvelle-Caledonie._ Les Editions du Pacifique.
Includes brief section on human intervention in the New Caledonian flora, and mentions the endangered palm _Pritchardiopsis jeanneneyi_ from the Prony region.

Schmid, M. 1982. Endemisme et speciation en Nouvelle-Caledonie. _Compte Rendu Seances Societe de Biogeographie_ 58(2): 52-60.
The New Caledonian flora comprises 44 endemic gymnosperm species, 250 endemic monocot species, and 1,900 endemic dicot species.

Schofield, E.K. 1973a. Annotated bibliography of Galapagos botany, 1836-1971. _Annals Missouri Botanical Garden_ 60(2): 461-477.
Includes references to articles by Ecuadorians and Galapagos resident which include data on factors influencing the vegetation.

Schofield, E.K. 1973b. A unique and threatened flora. _Garden Journal_ 23(3): 68-73.
Threats to the endemic flora of the Galapagos, such as domestic animals, wild goat herds, introduced flora, and agricultural activities, are discussed.

Schofield, E.K. 1973c. Galapagos flora: the threat of introduced plants. _Biological Conservation_ 5(1): 48-51.
"Two endemic species, _Scalesia pedunculata_ Hooker fil. and _Miconia robinsoniana_ Cogniaux, are especially endangered by farming practices."

Schofield, E.K. 1981. Hope for the Galapagos. _Garden_ (New York) 5(1): 16-21.
Efforts to protect Galapagos vegetation are now in motion.

Schofield, E.K. 1984. _Plants of the Galapagos Islands._ 159 pp. New York: Universe Books.
Designed as an excursion flora for interested visitors to the Galapagos.

School of Naval Administration, Hoover Institute, Stanford

University. 1948. Handbook on the Trust Territory of the Pacific Islands. 311 pp. Washington, D.C.: Office of the Chief of Naval Operations, Navy Department.
"Extensive plantings of the iron wood tree are found on Saipan in the northern Marianas where the Japanese reforested large areas with this tree in order to assure a source of fuel for the sugar mills there."

Schubert, E. 1961. Pitcairn Island is catching up. South Pacific Bulletin 11(2): 55-59.
"When the Bounty mutineers settled here in 1790 Pitcairn must have been almost completely covered with forest, but after 170 years of clearing and burning this has been reduced to a thin patch on the western tip of the island. The only certain indigenous trees are miro (Hibiscus tiliaceus) and rata (Metrosideros villosa).

Schultze-Motel, W. 1974. Die moose der Samoa - Inseln. Willdenowia 7: 333-408.
Monograph of Samoan mosses includes sections on human population explosion at the expense of the biota, and conservation.

Scowcroft, P.G. 1971. Koa: monarch of Hawaiian forests. Newsletter Hawaiian Botanical Society 10(3): 23-26.
Discusses threats of cattle, logging, weeds, and fungus disease to the koa (Acacia koa) forests.

Scowcroft, P.G. 1983. Tree cover changes in mamane (Sophora chrysophylla) forests grazed by sheep and cattle. Pacific Science 37(2): 109-119.
In forests of Mauna Kea, Hawaii, cattle browsing is more destructive than sheep browsing.

Scowcroft, P.G. and H.F. Sakai. 1984. Stripping of Acacia koa bark by rats on Hawaii and Maui. Pacific Science 38(1): 80-86.
"Koa (Acacia koa) is the most valuable native timber species in Hawaii. Bark stripping of young trees by rats, a common but unstudied phenomenon, may affect survival, growth, and quality of koa."

Sears, P.B. 1959. The ecology of man. Smithsonian Report for 1958: 375-398.
The human mind created the illusion that prosperity is the reward of virtue, to the extent that we now believe prosperity is itself a virtue and poverty is therefore a crime. To attain the desired prosperity, man converts and mutilates the biosphere, damaging the equilibrium of ecosystems forming his own life-support system.

Seiden, A. 1985. Lanai: talking tourism and planting pineapple. Aloha 8(1): 24-29.
Proposal for economic development, known as the "Lanai

Plan", calls for preservation of the island's ultimate resource, i.e., space itself, in an ever more crowded world. This Hawaiian island is the world's largest pineapple plantation, mostly 14,000 acres of pineapple in Palawai Basin, relieved by a few introduced Norfolk Island pines.

Serpell, J. 1983. Desert island risk. New Scientist 1356: 320; Threatened Plants Newsletter 11: 14-15.
Henderson Island biota threatened by intentions of human colonization.

Serpell, J., Collar, N., Davis, S., and S. Wells. 1983. Submission to the Foreign and Commonwealth Office on the Future Conservation of Henderson Island in the Pitcairn Group. 26 pp.
The possibility of introduced pigs and weeds becoming established would threaten the endemic flora, which comprises 10 flowering plant species including Santalum hendersonensis and Bidens hendersonensis.

Setchell, W.A. 1923. A reconnaisance of the vegetation of Tahiti, with special reference to that of the reefs. Carnegie Institution of Washington Yearbook No. 21 (for 1922): 180-187.
Environmental conditions in Tahiti foster the growth and spread of alien plants originally introduced as ornamentals and fuel suppliers, which crowd out some native fuel and food plants.

Setchell, W.A. 1926. Phytogeographical notes on Tahiti, I. Land vegetation. University of California Publications in Botany 12(7): 241-290.
Stenolobium stans, the "yellow elder", a native of Atlantic tropical America and cultivated in Tahiti as an ornamental since c.1845, is rapidly naturalizing on xeric mountain slopes, "and literally armies of young trees are seen ascending these slopes."

Shallenberger, R.J. 1975. Hawaii's endangered water birds. Defenders 50(6): 524-528.
Drainage of Hawaiian wetland plant communities reduces bird habitats.

Shallenberger, R.J. 1982. A seal slips away. Natural History 91(12): 48-53.
Tern I., in the Hawaiian archipelago, has a landscape profoundly modified by humans to accommodate a landing strip which covers the vast majority of the island's surface. In building the strip, engineers left some space for the endangered Hawaiian monk seals.

Shikama, T. 1942. On the deer of Ponape Island, Caroline Group. (In Japanese). Biogeographical Society of Japan,

Bulletin 12(6): 97-103.
Deer introduced from the Philippine Islands were still surviving in forests of Ponape.

Shimozono, F. and K. Iwatsuki. 1986. Botanical gardens and the conservation of an endangered species in the Bonin Islands. Ambio 15(1): 19-21.
Concerns propagation of Melastoma tetramerum, and includes discussion of human impact on forest vegetation of the Bonin Islands.

Shineberg, D. 1967. They Came for Sandalwood: A Study of the Sandalwood Trade in the South-West Pacific, 1830-1865. Melbourne, Australia: Melbourne University Press.
Details on nature and impact of sandalwood trade on Isle of Pines, New Caledonia.

Shiva, V. and J. Bandyopadhyay. 1983. Eucalyptus: a disastrous tree for India. The Ecologist 13(5): 184-187.
Discusses presumed effects of the water requirements of Eucalyptus on the ecological stability of reafforested lands in India. These considerations may find a wider application to other parts of the world, including the Pacific, where eucalypts have been introduced on a plantation scale.

Siegel, S.M. 1973. Lead: Aspects of its Ecology and Environmental Toxicity. 58 pp. Hawaii Botanical Science Paper No. 32. University of Hawaii.
"Parkland soils and vegetation in Honolulu, Hawaii are heavily contaminated with lead and zinc originating from automobiles."

Simmonds, H.W. 1934. Biological control of noxious weeds with specific reference to the plants Clidemia hirta (The Curse) and Stachytarpheta jamaicensis (Blue Rat Tail). Agriculture Journal (Fiji) 7(1): 3-10.
Fiji is overrun with weeds such as these.

Simmonds, H.W. 1956. A banana collecting expedition to South East Asia and the Pacific. Tropical Agriculture 33: 251-271.
Diploid wild (and cultivated) strains of Musa acuminata and taxa presumed to be conspecific with acuminata were sought as potential sources of new genes, as material for crossing with various hybridized bananas, and for replenishment of known (correctly identified) stocks in cultivation. On Samoa (Upolu and Savaii) M. banksii and forms of M. fehi were collected; Ensete calospermum and Musa maclayi were found on New Ireland.

Singh, A. and S. Siwatibau. 1977 (27 July). Medicinal Plants in Fiji and Other South Pacific Islands. Document WHO, WPR/DPM/77.2.

Produced by the World Health Organization of the United Nations.

Singh, B. 1982. Keynote Address: The Oceanian Realm, pp. 310-314, in McNeely, J.A. and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Washington, D.C.: Smithsonian Institution Press.
Includes discussion of current status of protected areas such as the 8 nature reserves in Fiji, and notes that land tenure systems have impeded establishment and effective management of protected areas in some Pacific localities.

Singh, Y.N. 1986. Traditional medicine in Fiji: some herbal folk cures used by Fiji Indians. Journal of Ethnopharmacology 15(1): 57-88.
There is some resurgence of interest in herbal cures in rural areas of Fiji. Eighty-six plant species from 39 families are treated, including notes on biodynamics. Useful Bibliography.

Siwatibau, S. 1984. Traditional environmental practices in the South Pacific: a case study of Fiji. Ambio 13(5-6): 365-368.
Agricultural systems as they impact on landscape and ecosystem.

Skottsberg, C., ed. 1920-1956. The Natural History of Juan Fernandez and Easter Island. 3 vols. 688 pp. Uppsala, Sweden: Almqvist & Wiksells.
Includes floristic impoverishment of Easter Island (1928).

Skottsberg, C. 1935. Notes on the vegetation in the Cumberland Bay Caves, Masatierra, Juan Fernandez Islands. Ecology 16(3): 364-374.
It is likely that man has acted as the agent of distribution of the cave fern and bryophyte flora in many cases, by transporting spores and fragments of thalli from one cave to another. The caves were excavated by buccaneers in the 17th and 18th centuries, and in the 19th century were used to hold political prisoners.

Skottsberg, C. 1940. Report of the Standing Committee for the Protection of Nature In and Around the Pacific for the years 1933-1938. Proc. Sixth Pacific Science Congress 4: 499-542.
Includes accounts of status of preservation of various Pacific islands to the year 1938, by means of systematically answered questionnaires (37 questions). F.R. Fosberg is respondant for Pacific.

Skottsberg, C. 1953a. The Vegetation of the Juan Fernandez Islands. 167 pp. + 58 plates. Uppsala, Sweden: Almqvist & Wiksells.
Includes mention of history of goat and exotic plant (weed) introductions; photos of deforested valleys; history of sandalwood exploitation (Santalum fernandezianum); and status of specifically identified endemic plant species.

Skottsberg, C. 1953b. Report of the Standing Committee for the Protection of Nature In and Around the Pacific for the years 1939-1948. Proc. Seventh Pacific Science Congress 4: 586-597.
Contains pertinent vegetational observations from New Caledonia, Galapagos, and the individual Hawaiian Islands.

Skottsberg, C. 1954. A Geographical Sketch of the Juan Fernandez Islands. 103 pp. + 100 plates. Uppsala, Sweden: Almqvist & Wiksells.
On Masafuera Island the original plant cover (1) was impacted by complete extermination of sandalwood, (2) had foreign grasses preventing the germination of native tree seeds in cleared spaces, (3) had goats devouring arborescent Compositae and endemic herbs, and (4) was subjected to the indignity of forest cutting by convicts interned there between 1908 and 1917.

Skottsberg, C. 1957. The vegetation of the Juan Fernandez and Desventuradas Islands. Proc. Eighth Pacific Science Congress 4: 181-185.
On Masafuera, forest destruction dating back perhaps two centuries has been going on in connection with the activities of the convict settlement, established there by the Chilean government.

Skottsberg, C. 1961. The status of conservation in Chile, Juan Fernandez, and Easter Island. Proc. Eighth Pacific Science Congress 6: 128-131.
The Juan Fernandez Islands were declared a Chilean national park in 1935, with hopes that unlawful cutting of the endemic palm (Juania australis) and the export of endemic tree ferns would cease. Unfortunately, some time before 1945 Masatierra National Park was made a sheep farm. The present management of Easter Island National Park clearly works against the rules expressed in the Government Act of 1935.

Skottsberg, C. 1962. Report of the Subcommittee on Nature Protection. Proc. Ninth Pacific Science Congress 4: 29-38.
Excellent description of the mindless destruction of vegetation on Masatierra, Santa Clara I., and Masafuera (Juan Fernandez Is.) due to human foibles.

Smathers, G.A. 1969. Plant succession and recovery in the 1959 Kilauea Iki Devastation Area, Hawaii Volcanoes National Park. National Park Service, Office of Natural Science Studies, Annual Report 1968: 59-72.
Includes data on recovery of vegetation after volcanic eruption.

Smathers, G.A. and D.E. Gardner. 1979. Stand analysis of an invading firetree (*Myrica faya* Aiton) population, Hawaii. Pacific Science 33(3): 239-255.
More knowledge of the behavior of firetree in its natural habitats in Macaronesia (Canary Is., etc.) is needed in order to help find controls to effectively eliminate or stabilize its spread as an exotic in Hawaii.

Smathers, G.A. and D. Mueller-Dombois. 1974. Invasion and Recovery of Vegetation After a Volcanic Eruption in Hawaii. 129 pp. National Park Service Scientific Monograph Series No. 5, and Island Ecosystems IRP/IBP Hawaii Contribution No. 38.
Successional studies conducted after devastating eruption in 1959 indicate that "there appears to be no threat of native plants to be replaced by exotics on these new volcanic substrates."

Smith, A.C. 1970. The Pacific as a Key to Flowering Plant History. 28 pp. Honolulu, Hawaii: Harold L. Lyon Arboretum of the University of Hawaii.
The Asia - Australia region contains 53 of the 60 extant primitive angiosperm families, including the Amborellaceae with primitively vesselless wood from New Caledonia, and the Degeneriaceae with primitive stamens and carpels from Fiji. These plants and their natural habitats should be conserved for scientific evolutionary research.

Smith, C.W. 1971. Lichens and air pollution. Newsletter Hawaiian Botanical Society 10(2): 13-15.
Absence of lichens on trees along certain Honolulu streets is attributed to motor vehicle exhaust emissions.

Smith, N., ed. 1977. Lord Howe Island. 42 pp. Sydney, Australia: The Australian Museum.
Includes discussion of values of environmental conservation of the island, versus exploitation.

Smith, S.V., *et al.* 1978. Kaneohe Bay Sewage Relaxation Experiment: Pre-Diversion Report. 166 pp. Kaneohe, Hawaii: Hawaii Institute of Marine Biology, University of Hawaii at Manoa.
Kaneohe Bay is a semi-enclosed embayment on the

northeast (windward) coast of Oahu. Concomitant with recent dramatic growth in human population numbers in the Kaneohe watershed, several human impacts on the bay environment have been at work, of which the most profound are dredging, modified runoff patterns, increased sewage discharge, introduction of exotic plant and animal species, and heavy fishing pressure.

Smithsonian Institution. 1975. Report on Endangered and Threatened Plant Species of the United States. 200 pp. Committee on Merchant Marine and Fisheries, Serial No. 94-A. U.S. Congress. Washington, D.C.: U.S. Government Printing Office.
Lists of endangered, threatened and presumed extinct plants of Hawaii provided by Dr. F.R. Fosberg, Department of Botany, Smithsonian Institution, Washington, D.C.

Sneed, M.W. 1979. Palm collecting in the South Pacific: island hopping to Australia and back. Principes 23(3): 99-127.
Includes the rare Fijian *Neoveitchia storckii*.

Sneed, M.W. 1983. Forty years after chaos: Guadalcanal has beautiful palms. Principes 27(1): 31-33.
Guadalcanal (Solomon Is.) was heavily damaged as part of the Pacific War Theater military operations in World War II. However, some palm gardens have been rejuvenated to good condition and are flourishing.

Snow, P. and S. Waine. 1979. The People From the Horizon: An Illustrated History of the Europeans Among the South Sea Islanders. 296 pp. Oxford, England: Phaidon.
Includes examples of ravages of the sandalwood trade.

Sohmer, S.H. 1978. Kaluua Gulch revisited. Newsletter Hawaiian Botanical Society 15(1): 23-24.
Noteworthy Hawaiian plants in this habitat are discussed.

Sorensen, J. 1974. Remote Oceanic Islands: Approaches to Conservation of an International Resource. 26 pp. University of California, Berkeley: Institute of Urban and Regional Development.
Plots 26 inventory factors and measures onto a matrix of 10 types of suitability of an island for alternative uses, in order to arrive at an inventory of the resource stock of an oceanic island. The major problem-areas of oceanic islands are: overpopulation; degradation of natural resources; colonial rule vs. island self-determination; extinction of distinct island races; human and crop diseases, animal and plant pests; property and resource ownership; extinction of species from island or world; and disruption, corruption or loss of

indigenous cultural patterns.

Sorensen, J. 1977. Andropogon virginicus (Broomsedge). Newsletter Hawaiian Botanical Society 16(1-2): 7-22.
An obnoxious pest seemingly introduced by accident into Hawaii pre-1932.

Souder, P. 1968. Report on Conservation Areas on Guam. 2 pp., mimeo. Agana, Guam: Micronesian Area Research Center.
In 1968, only 3,594 acres or 2.65 percent of Guam's total area was devoted to conservation. Report lists conserved areas.

Sparre, B. 1973. Plants from Robinson Crusoe's island. Taxon 22(1): 171.
Complaint that scientists have over-collected rare plants on Juan Fernandez Islands.

Spate, O.H.K. 1979. The Spanish Lake. 330 pp. Minneapolis, Minnesota: University of Minnesota Press.
Concerning the era when the Manila galleons traversed the Pacific from Middle and South America to the Philippines, non-stop travel except for one stop in Guam, "Plants introduced (to Asia) via the Pacific included acacias, capsicums, groundnuts, papaya, indigo, manihot, tobacco; maize was probably already in Southeast Asia before any Spanish introduction...There was little plant transferral from Asia; in contrast to the westbound sailings, the cold on the northern reaches of the eastwards run was probably enough to inhibit success with seedlings."

Spatz, G. and D. Mueller-Dombois. 1972a. Succession Patterns After Pig Digging in Grassland Communities on Mauna Loa, Hawaii. 44 pp. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 15. Honolulu, Hawaii: University of Hawaii.
"It was found that pig digging greatly enlarges the component of introduced species in communities with a former high percentage of native species." See similar article in Phytocoenologia 3(2-3): 346-373 (1975).

Spatz, G. and D. Mueller-Dombois. 1972b. The Influence of Feral Goats on Koa (Acacia koa Gray) Reproduction in Hawaii Volcanoes National Park. 16 pp. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 3. Honolulu, Hawaii: University of Hawaii.
If high numbers of goats are permitted to exist, the koa stands will become senile and the remnant trees will eventually die a normal physiological death, as is presently demonstrated in the parallel ecosystem on Mauna Kea, where cattle interfere with the koa reproduction cycle. Goat extermination is suggested to remedy the

situation.

Spatz, G. and D. Mueller-Dombois. 1973. The influence of feral goats on koa tree reproduction in Hawaii Volcanoes National Park. Ecology 54(4): 870-876.
Several negative effects are observed.

Spence, G.E. and S.L. Montgomery. 1976. Ecology of the dryland forest at Kanepu'u, Island of Lanai. Newsletter Hawaiian Botanical Society 15(4-5): 62-80.
To preserve this forest, fires should be suppressed, axis deer should be limited, and conservation re-zoning should be enforced.

Spoehr, A. 1954. Saipan: the ethnology of a war-devastated island. Fieldiana: Anthropology 41: 1-379.
The vegetation of Saipan has been so altered by man that its original character is no longer preserved. Only in a few small restricted areas on Mount Tapochau and along the cliffs and steep slopes of the east coast are there patches of forest that probably resemble the vegetation of early days.

Squire, S. 1984. Frozen assets. National Wildlife 22: 7-13.
Includes discussion of exotics introduced to Hawaii.

Stager, K.E. 1964. The birds of Clipperton Island, Eastern Pacific. Condor 66: 357-371.
Mentions destructive activity by feral pigs.

Stark, J.T., et al. 1958. Military Geology of Truk Islands, Caroline Islands. 205 pp. Tokyo: H.Q. US Army Pacific.
"Most of the present grassland areas were cleared during the latter years of the Japanese administration...When abandoned at the end of World War II, these areas were revegetated with Ischaemum (shortgrass), Gleichenia (fern), and Merremia (vine)."

State Department of Land and Natural Resources (Hawaii). 1976. Forestry Potentials for Hawaii. 68 pp. U.S. Forest Service, Region 5.
Feral pigs and other vectors have spread the aggressive exotic "banana poka" vine over at least 25,000 acres, drastically altering the forest in some areas. It has been estimated that at least 150,000 acres are infested with undesirable exotic plants such as black wattle, fire-tree, banana poka, melastoma, lantana, gorse, and blackberry.

Stebbins, G.L. 1966. Variation and adaptation in Galapagos plants, pp. 46-54, in Bowman, R.I., ed., The Galapagos. Berkeley and Los Angeles: University of California Press.

Characteristics of endemic plant species of the Galapagos, evolved in isolation, are discussed.

Steenis, C.G.G.J. van. 1964. On the origin of island floras. Advancement of Science (May 1964): 79-92.
The author is proponent of theory of a land origin of Pacific floras, an alternative to the diffusionist theory. Endemic genera of various islands are mentioned.

Steenis, C.G.G.J. van. 1965. Man and plants in the tropics: an appeal to Micronesians for the preservation of nature. Micronesica 2(1): 61-65.
Suggests flora should be inventoried, living collections should be maintained in botanical gardens, and nature reserves laid out in Micronesia.

Steenis, C.G.G.J. van. 1972. Axis deer tragedy in Hawaii. Flora Malesiana Bulletin 26: 2017.
Remarks on the vegetation damage which may occur as a result of proposed experimental introduction of axis deer to a large enclosure on Mauna Kea, for sport hunting.

Steinberg, R. 1978. Island Fighting. 208 pp. Alexandria, Virginia: Time - Life Books.
In Pacific island combat areas during World War II, enemy defense personnel were often deployed in nearly impregnable concrete bunkers, limestone caves, subterranean tunnels, reinforced pillboxes, trenches, blockhouses and gun emplacements. Underbrush and dense taller vegetation which presented an impediment to access and dislodgement of enemy resistance was either purposefully or inadvertently eliminated. Penetration methods and instruments on difficult terrain included bomber-strafer airplanes; naval bombardment; airplane rockets; hand grenades; dynamite, TNT and demolition charges; armored bulldozers; one- and two-man flamethrower teams; tanks; amtrac-mounted flamethrowers (amtracs are amphibious tractors, known as LVT, for "Landing Vehicle, Tracked"); long-range flamethrowers mounted on tanks; and artillery, mortar and napalm attacks. In many cases, the Seabees (U.S. Navy Construction Battalions) were called in to build roads, airstrips, naval bases and related facilities, which required clearing and flattening of much remaining atoll vegetation, involving utilization of bulldozers, detonation blasting of stumps and coral, power-shovels, dynamite-assisted quarrying, road surface graders, Marston mats, trenching machines, and earth-movers. Thus, the genesis of a secondary flora on many Pacific islands. Illustrated.

Stemmermann, L. 1980. Observations on the genus Santalum (Santalaceae) in Hawaii. Pacific Science 34(1): 41-54.

In the lowlands of Maui, habitat destruction, and perhaps the effects of sandalwood trade, is extensive. Plants such as Santalum freycinetianum now exist only in relict pockets.

Stemmermann, L., Higashino, P.K., Char, W. and L. Yoshida. 1986. Botanical survey of the Kahuku Training Area, Oahu, Hawaii. Newsletter Hawaiian Botanical Society 25(3): 90-118.
The training area consists of 9,646 acres leased by the U.S. Army, extending from near sea level to the coast of the Koolaus (approx. 2,000 ft.). Includes discussion of vegetation types, rare plants and limitations of survey. Ochrosia compta, two species of Tetraplasandra, and Reynoldsia sandwicensis were located.

Stemmermann, L. and F. Proby. 1978. Inventory of Wetland Vegetation in the Caroline Islands. Vol. I. Wetland Vegetation Types. 231 pp. Honolulu, Hawaii: VTN Pacific. Prepared for Pacific Ocean Division, US Army Corps of Engineers.
Discusses invasive plants, flora of bomb craters, and several rare plants. Volume II. Wetland Plants. 382 pp. (1978) warns of the noxious potential of the now rare Clidemia hirta on Palau.

Stewart, M. 1973. New species found on Kauai. Bulletin Pacific Tropical Botanical Garden 3(4): 71.
Recounts various species of Hibiscadelphus (Malvaceae).

Stine, P.A. 1986. Refuge established for endangered Hawaiian forest birds. Endangered Species Technical Bulletin 11(1): 5.
The Hakalau Forest National Wildlife Refuge on island of Hawaii will protect several potentially threatened plants, including species of Clermontia, Cyanea, Gouldia and Platydesma.

St. John, H. 1946. Endemism in the Hawaiian flora, and a revision of the Hawaiian species of Gunnera (Haloragidaceae). Hawaiian Plant Studies 11. Proceedings California Academy of Sciences, ser. 4, 25(16): 377-419. Reprinted as pp. 517-527, in Kay, E.A., ed. 1972. A Natural History of the Hawaiian Islands: Selected Readings. Honolulu, Hawaii: University of Hawaii.
Pertinent data on Hawaiian endemic plants.

St. John, H. 1947. The history, present distribution, and abundance of sandalwod on Oahu, Hawaiian Islands. Hawaiian Plant Studies 14. Pacific Science 1(1): 5-20.
History of the extensive, destructive trade in sandalwood, a monopoly of the Hawaiian kings.

St. John, H. 1954a. Ferns of Rotuma Island, a descriptive

manual. B.P. Bishop Museum, Occasional Papers 21(9): 161-208.
More than 90 percent of the land area of Rotuma I., near Fiji, is planted in coconuts for copra.

St. John, H. 1954b. The vegetation of Hawaii at the time of Capt. James Cook in 1778-79, and a comparison with its present status. Eighth Congr. Int. Bot. Rapp. Comm. 21 a 27: 176-177.
Origin of adventive plants in Hawaii is probed.

St. John, H. 1957a. Adventive plants in the Marshall Islands before 1941. Proc. Eighth Pacific Science Congress 4: 227-228.
Brief outline of successive waves of weeds occupying the Marshalls, until the 1890's development of coconut plantations opened up even more habitats for weed encroachment.

St. John, H. 1957b. Vegetational provinces of the Pacific: Hawaiian. Proc. Eighth Pacific Science Congress 4: 56-57.
The natural flora of Hawaiian zones having a rainfall of 20 to 60 inches annually at lower altitudes, has been virtually exterminated by man and his animals.

St. John, H. 1959. Botanical novelties on the island of Niihau, Hawaiian Islands. Hawaiian Plant Studies 25. Pacific Science 13(2): 156-190.
Includes account of the first discovery, in an area of grazing sheep and cattle, of the endangered endemic palm *Pritchardia aylmer-robinsonii*.

St. John, H. 1960. Flora of Eniwetok Atoll. Pacific Science 14(4): 313-336.
Heavy bombing and fighting on Eniwetok in February 1944 "caused general devastation on the largest islet, Eniwetok Islet, and on several others. It probably exterminated some of the rarer plant species."

St. John, H. 1966. Monograph of *Cyrtandra* (Gesneriaceae) on Oahu, Hawaiian Islands. B.P. Bishop Museum Bulletin 229: 1-465.
Details history of forest destruction in Schofield Saddle region: "Now the forest is so completely destroyed that prolonged research was needed to reveal that it once existed."

St. John, H. 1977. The flora of Niuatoputapu Island, Tonga. Pacific Plant Studies 32. Phytologia 36(4): 374-390.
"The vegetation of Niuatoputapu has been extensively modified as a result of some 3,000 years of Polynesian occupation."

St. John, H. 1979. A new Stenogyne (Labiatae). Hawaiian Plant Studies 84. Phytologia 41(5): 305-308.
On the island of Hawaii in the saddle area between Mauna Kea and Mauna Loa volcanoes, Stenogyne pohakuloaensis occurs in a lava fissure in vegetation that has suffered from the grazing of feral goats and from military maneuvers and cannon fire, for it is now a military training area.

St. John, H. and A.C. Corn. 1981. Rare Endemic Plants of the Hawaiian Islands, Book I. Honolulu, Hawaii: Department of Land and Natural Resources.
Details of status, threats, and habitat of 68 threatened plant species of Hawaii.

St. John, H. and F.R. Fosberg. 1937. Vegetation of Flint Island, Central Pacific. B.P. Bishop Museum, Occasional Papers 12(24): 3-4.
"The original vegetation of this island has been practically destroyed, and the island is now an intensively cultivated copra plantation."

St. John, H. and W.R. Philipson. 1962. An account of the flora of Henderson Island, South Pacific Ocean. Transactions Royal Society of New Zealand, Botany 1(14): 175-194.
"Each summer, when possible, they (Pitcairn islanders) sail in whale boats the 90 miles to windward to Henderson Island, land at the north end and fell trunks of "milo", Thespesia populnea and sandalwood, Santalum hendersonense. From the beautiful reddish wood of the latter they make carvings to be offered for sale to passengers on passing steamers."

Stockman, J.R. 1947. The Battle for Tarawa. 86 pp. Washington, D.C.: U.S. Marine Corps.
Tarawa, devastated island of the Pacific Combat Theater in 1943, is shown with many photos of vegetation destroyed due to military operations in World War II.

Stoddart, D.R. 1965. Geography and the ecological approach: the ecosystem as a geographic principle and method. Geography 50(3): 242-251.
Includes brief indications of studies of Pacific ecosystems impacted by introduced mammals, e.g. Clipperton I., Fiji Is.

Stoddart, D.R. 1967. Organism and ecosystem as geographical models, pp. 511-548, in Chorley, R.J. and P. Haggett, eds., Models in Geography. London: Methuen & Co., Ltd.
Ecosystem modelling as an activity for geographers, including references to articles on the interaction of man, plants and animals in Fiji and Hawaii.

Stoddart, D.R. 1968a. Isolated island communities. Science Journal 4(4): 32-38.
Includes map indicating locales of threats posed to Pacific islands by the development of international airports, airstrips, military bases, weapons testing sites, and guano and phosphate mining.

Stoddart, D.R. 1968b. Catastrophic human intervention with coral atoll ecosystems. Geography 53(1): 25-40.
Includes effects of coconut plantations, airstrip construction, and nuclear weapons testing, on the Pacific flora, e.g. the disappearance of Cordia forest on Canton I.

Stoddart, D.R. 1969. Sand cays of eastern Guadalcanal. Philosophical Transactions, Royal Society B255: 403-432.
"Field mapping of the Marau cays suggests a major distinction between the vegetation of islands much disturbed by man, dominated by coconuts and Casuarina, and the less disturbed islands (such as East, Keura, North, Horohato and Tarvarau) which are still largely covered with broadleaf woodland."

Stoddart, D.R. 1971. Conservation of the Phoenix Islands, Central Pacific Ocean. 20 pp. Report to the Southern Zone Research Committee, Royal Society, Department of Education and Science, and Foreign and Commonwealth Office.
Recommendations for preserving the fragile ecosystems of the Phoenix Is.

Stoddart, D.R. 1975. Reef islands of Aitutaki. Atoll Research Bulletin 190: 59-72.
Mentions that vegetation of the Ootu peninsula of Aitutaki was considerably leveled and cleared for runway development in World War II, and still is periodically cleared.

Stoddart, D.R. 1976. Scientific Importance and Conservation of Central Pacific Islands. 28 pp. Report to the Southern Zone Research Committee, Royal Society, Department of Education and Science, and Foreign and Commonwealth Office.
Includes discussion of disturbances caused by human activities in the central Pacific.

Stone, B.C. 1963. The role of pandanus in the culture of the Marshall Islands, pp. 61-82, in Barrau, J., ed., Plants and the Migrations of Pacific Peoples. 136 pp. Honolulu, Hawaii: Bishop Museum Press.
"Pandanus trunks are split down the middle for use in light construction, especially for walls, and were so much employed by American armed forces in the Gilberts during World War II that the area saw a great reduction

in the Pandanus population."

Stone, B.C. 1967a. The phytogeography of Guam, Marianas Islands. Micronesica 3: 67-73.
Sixty-three percent of the total Guam flora (585 out of 931 species) is introduced by man. Introduced and native species are categorized under several headings for discussion. A large number of the introduced plants are from Mexico, Central or South America, and may be traced to the Spanish galleon route from Acapulco, Mexico, to Guam, and on to Manila in the Philippines. Most endemics occur on coral substrate.

Stone, B.C. 1967b. The flora of Romonum Island, Truk Lagoon, Caroline Islands. Pacific Science 21(1): 98-114.
"Very little, if any, of the original vegetation is left intact."

Straatmans, W. 1964. Dynamics of some Pacific island forest communities in relation to the survival of the endemic flora. Micronesica 1(1 & 2): 113-122.
Concerns 'Eua I. in Tonga Is. "Land clearing, ring-barking, firing, logging and crop-growing under increasing population pressure has resulted in drastic changes which cross-pattern the spontaneous dynamics of the virgin forests."

Strauss, T. 1978. The Cousteau Odyssey: Blind Prophets of Easter Island. 58 min. running time. A Cousteau Society Production. J. & P. Cousteau, Executive Producers.
This film discusses the former civilization of Easter Island, or Rapa Nui, which died trying to destroy its own habitat. As the island was denuded of timber, the people became impoverished and sought the natural shelter of caves . Social disorder became commonplace as overpopulation and food shortages continued. Strange petroglyphs of flowers and large trees survive to indicate the formerly flourishing woodlands, and the huge totemic stone figures, mute celebrities of the island's history, now stand amid the short grass. Today, the handful of descendants of the ancient people have no conscious recollection that wood was once plentiful on their depleted island.

Street, J.M. 1960. Eniwetok Atoll, Marshall Islands. 63 pp. Library brochure prepared for Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
"Bogombogo Islet, which was denuded by a nuclear shot set off at a distance of 2.3 miles in November 1952, was re-covered with a heavy growth of Scaevola and Messerschmidia when examined in April, 1954."

Strong, M.F. 1976. Environment and man's future in the

Pacific, pp. 99-11, in Scagel, R.F., ed., *Mankind's Future in the Pacific.* 198 pp. Vancouver: University of British Columbia Press.
Includes mention of various Pacific islands which have become "ecologically bankrupt", such as Banaba (or, Ocean I. in the Gilberts), and large desecrated areas of New Caledonia, including the importance of restoring centuries of damage in the Galapagos. See similar article in *SPC Environment Newsletter* 2: 10-17 (1975).

Stuessy, T.F. and O. Silva. 1983. The evolution of the flora of the Juan Fernandez Islands. *Rep. Chilean Univ. Life* 15: 3-6.
Some endemics have unusual life-forms.

Stuessy, T.F., Sanders, R.W. and O.R. Matthei. 1983. *Juania australis* revisited in the Juan Fernandez Islands, Chile. *Principes* 27(2): 71-74.
Status of a rare endemic palm.

Stuessy, T.F., Sanders, R.W. and M. Silva. 1984. Phytogeography and evolution of the flora of the Juan Fernandez Islands: a progress report, pp. 55-69, in Radovsky, F.J., Raven, P.H. and S.H. Sohmer, eds., *Biogeography of the Tropical Pacific.* 221 pp. B.P. Bishop Museum, Special Publication No. 72.
"The main reason for the decline in the endemic flora is the destruction by domesticated and feral animals including goats, sheep, cattle, coatimundis, rabbits and horses."

Summerhays, B. 1984. The endangered species of Darwin's islands. *Environment Southwest* 504: 3-6.
Environmental perturbations in Galapagos are mentioned.

Svenson, H.K. 1963. Opportunities for botanical study on the Galapagos Islands, pp. 53-58, in Galapagos Islands: a unique area for scientific investigations. *Occasional Papers, California Academy of Sciences*, No. 44.
Dry areas of the islands have the more pronounced endemism.

Svihla, A. 1936. *Rana rugosa* Schlegel. *Mid-Pacific Magazine* (April-June): 124-125.
It is possible that this Japanese and Korean frog may have arrived in the Hawaiian Islands (where it is known from Oahu and Maui) by means of man as an agent of plant dispersal, i.e., tiny frog eggs inadvertently concealed among the roots of aquatic plants shipped from Japan. Breakdown of frog's breeding rhythm postulated as a result.

Svihla, A. 1936. The Hawaiian rat. *The Murrelet* 17: 2-14.
In a strange reversal of the overwhelmingly provable

concept that introduced plants are usually deleterious to the native biota, the indigenous "iole" or Hawaiian rat, Rattus hawaiiensis, actually prefers to live in gullies thick with growths of introduced guavas, cactus and lantana, rather than in dry areas where the native vegetation is sparse.

Sykes, W.R. 1969. The effect of goats on vegetation of the Kermadec Islands. Proc. New Zealand Ecological Society 16: 13-16.
On the Kermadec Is., located between Tonga and New Zealand, and particularly with respect to Raoul I., palatable indigenous flora will continue to disappear due to grazing pressure by goats, unless goats are exterminated.

Sykes, W.R. 1980. Botanical Science, pp. 9-67, in Bibliography of Research on the Cook Islands. New Zealand Nat. Comm. Unesco, DSIR, Lower Hutt.
Cook Islands are New Zealand territory located by Tonga.

Sykes, W.R. 1981. The vegetation of Late, Tonga. Allertonia 2(6): 323-353.
To avert the threat of potentially dangerous weed spread, all visible plants of Mimosa pudica on the lava cliff dwelling site were eradicated by the author.

Tabata, R.S. 1980. The native coastal plants of Oahu, Hawaii. Newsletter Hawaiian Botanical Society 19: 2-44.
Threats to indigenous plants in coastal habitats discussed in detail; includes checklist of plants and recommended protective measures for them.

Tagawa, T.K. 1976. Endangered species in Hawaii: effect on other resource management. Newsletter Hawaiian Botanical Society 15(1): 7-14.
Discloses a mounting apprehension concerning the bureaucratic burdens involved in protecting officially listed Hawaiian plants and critical habitats. Followed by rebuttal article by Lamoureux, C.H., loc. cit. 14-21 (1976).

Takahashi, M. and J.C. Ripperton. 1949. Koa Haole (Leucaena glauca): Its Establishment, Culture, and Utilization as a Forest Crop. 56 pp. Bulletin 100. Honolulu, Hawaii: University of Hawaii Agricultural Experiment Station.
Background information on a plant which has since become, due to improper management, an invasive pest on several Pacific islands.

Taketa, K.H. 1987. Hawaii's islands of life: a campaign to stem the tide of extinction. The Nature Conservancy News 37(1): 4-5.

Briefly describes the objectives of TNC Islands of Life Campaign recently initiated in the State of Hawaii, along with mention of TNC's accomplishments of the past decade.

Takeuchi, W. 1980. Unpublished manuscripts. Status reports on Bidens cuneata Sherff (Compositae); Schiedea adamantis St. John (Caryophyllaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Takeuchi, W. 1982. Unpublished manuscript. Status report on Brighamia spp. (Lobeliaceae). Washington, D.C.: U.S. Department of the Interior.
Endangered plants of Hawaiian Islands.

Talbot, F.H. and C.E. Holdren. 1985. The protection of coral reef ecosystems: the size of viable reserves. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 375. (Abstract)
"Economic development in the form of tourism; overfishing or poor fishing technique; siltation from housing development, forestry, agriculture or mining; or pollution from increasing city size and industrial growth, often threaten the long term productivity or even the survival of many coral reefs."

Talbot, L.M. 1969. Highlights of conservation in the International Biological Programme in the Asia-Pacific Region. Malaysian Forester 32: 391-394.
Discusses nature conservation in the Pacific.

Tannowa, T. and A. Yoshida. 1975. Plant Collecting in the Ogasawara Islands: Collecting and Breeding. Institute of Breeding Research, Tokyo, Vol. 37, No. 8. (In Japanese)
Rare endemic plants, principally of Hahajima I. and Mukojima I.

Tannowa, T., Yoshida, A. and K.R. Woolliams. 1976. Tentative list of rare and endangered plants of the Ogasawara Islands. Notes Waimea Arboretum 3(2): 10-12.
Endemic Ogasawara plants requiring conservation.

Taylor, J.L. 1951. Saipan: a study in land utilization. Economic Geography 27(4): 340-345.
Includes vegetation and land use.

Taylor, R.H. 1968. Introduced mammals and islands: priorities for conservation and research. Proc. New Zealand Ecological Society 15: 61-67.
Exotic mammals should not be permitted to gain a foothold on unmodified islands, and they also should be removed from unstable, actively degrading islands. But the control of introduced mammals on modified, stable

islands with balanced ecosystems, or on nearly stable islands with declining mammal populations, should not be attempted solely as a conservation measure unless the need is confirmed by sufficient ecological research.

Taylor, W.R. 1950. Plants of Bikini and Other Northern Marshall Islands. 227 pp. Ann Arbor, Michigan: University of Michigan Press.
Damage to terrestrial vegetation on various islands as a result of military installations and atomic bomb stations is noted.

Telfer, T.C. 1971. Kauai's blacktail deer. Aloha Aina 2(1): 16-18.
The deer were introduced from Oregon to Kauai because, "In view of the goat control measures, the needs and desires of the Island sport hunters had to be considered."

Templet, P.H. 1986. American Samoa: establishing a coastal area management model for developing countries. Coastal Zone Management Journal 13(3-4): 241-264.
Pressures on Samoan coastal ecosystems are treated.

Tenney, E.D. 1909. Oahu water resources. Hawaiian For. Agr. 6: 130-132.
Remarks on Kahoolawe deforestation and ensuing climatic changes.

Tercinier, G. 1974. Les sols de l'Ile de Mangareva (Gambier): etude pedologique temoin d'une ile haute de la Polynesie Francaise. Cahiers du Pacifique 18(2): 341-457.
Human activity destroyed the forest cover and fragile soil of Mangareva, promoting erosion and sedimentation.

Terrell, J. 1976. Island biogeography and man in Melanesia. Arch. and Phys. Anthrop. in Oceania 11(1): 1-17.
Biogeography, the study of distribution patterns of plants and animals in time and space, has been an integral part of human geography for generations, although some investigators do not wish to consider human beings as animals. Animals or not, our increasing and diffusing populations are consuming and converting a great deal of biomass, including native forests and vegetation.

Thaman, R.R. 1974a. Lantana camara: its introduction, dispersal and impact on islands of the tropical Pacific Ocean. Micronesica 10(1): 17-39.
Documents the presence of lantana on many islands and its adverse alteration of many floras, in conjunction with other modifications by man. Good, long Bibliography.

Thaman, R.R. 1974b. Tongan agricultural land use: a study of plant resources, pp. 153-160, in Proc. International Geographical Union Regional Conference and Eighth New Zealand Geography Conference. Palmerston North, New Zealand: New Zealand Geographical Society.
Owing to population pressure (over 300 persons per square kilometer in 1971) and over 3,000 years of human occupance, very little primary vegetation remains on Tongatapu. The existing vegetation communities provide gene pools of plants commonly found in either a protected or wild state on many bush allotments.

Thaman, R.R. 1976. The Tongan Agricultural System. 433 pp. Suva, Fiji: University of the South Pacific.
Includes details of Tongan plant associations, weeds , and how people interact and utilize indigenous flora. Native forest species on Tongatapu are rapidly being eliminated as a result of the need for firewood and timber for banana "shooks" and other purposes.

Theobald, W.L. 1976. Proposed road through garden defeated. Bull. Pacific Tropical Botanical Garden 6(3): 64-68.
Scenic road proposed by the Hawaii State Department of Transportation, which would have gone through the Lawai Valley and the PTBG, was aborted due to pressures from conservationists.

Theobald, W.L. 1978. Economic crop survey: New Hebrides and New Caledonia. Bull. Pacific Tropical Botanical Garden 8(4): 81-85.
In New Caledonia, "Cattle grazing is significant for the local population and there is a timber industry which is rapidly depleting the native flora."

Theobald, W.L. 1980. The nation's tropical garden. Pacific Horticulture 41(2): 28-34.
A primary goal of the Pacific Tropical Botanical Garden is to grow endangered plants.

Thibault, J.-C. 1975. Rapa Iti: l'ile de la derniere chance. Te Natura o Polynesia 4: 8-10.
Introduced plants have abundantly multiplied and therefore significantly modified the environmental milieu of Rapa Iti.

Thompson, P.G. 1965. Goat breeding in Fiji. South Pacific Bulletin 15(2): 28-30.
"Goats were well established in Fiji before Cession in 1874, and Angora goats were run on the Nananu Is., at Nadi, on Mago I., and probably elsewhere...Fiji's large Indian population much prefers goat meat to mutton." Control of stock numbers to prevent overgrazing is suggested.

Thorby, R.G. 1954. Afforestation in the Cook Islands. South Pacific Bulletin 4(4): 15-16.
Deforested areas and sheet-washed slopes should be reafforested before they become irremediably ruined. Acacia, Eucalyptus and Albizzia falcata are being tested for this purpose.

Thorne, R.F. 1965. New Caledonia, island of botanical opportunity. Newsletter Hawaiian Botanical Society 4(1): 1-3.
"The area of native vegetation on la Grand-Terre is rapidly being diminished by frequent and extensive burning, destructive prospecting and mining, timbering, over-grazing, and other disturbances attributable to civilized man."

Thorp, T.E. 1960a. Wake Island. 42 pp. Library brochure prepared for the Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
Original vegetation patterns on Wake have been considerably modified by "(1) wartime construction work, and (2) by damage resulting from air and sea bombardments of the islands by both Japanese and U.S. forces."

Thorp, T.E. 1960b. Midway Islands. 47 pp. Library brochure prepared for the Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
Includes brief history of the considerable modification of the vegetation by introduction of exotic species, and construction work.

Thorp, T.E. 1960c. Johnston Island. 40 pp. Library brochure prepared for the Pacific Missile Range, Point Mugu, California. Riverside, California: University of California.
Discusses incidence of naturalized weeds, some of which may have come in with nursery stock from Hawaii.

Tindle, R.W. 1983. Galapagos conservation and tourism: eleven years on. Oryx 17(3): 126-129.
Minimization of tourist impact is desired.

Titcomb, M. 1969a. The axis deer: impending threat to the Big Island. Elepaio 30(3): 21-25.
Deer may turn out to have the same "nuisance value" as feral goats in Hawaii.

Titcomb, M. 1969b. Axis deer: welcome or not? Elepaio 30(6): 52-54.
"Recent observers have called East Molokai's forest a disaster area, as to its vegetation." (Hawaiian Islands)

Tokyo Metropolitan Government. 1969-1970. Survey Report on Nature Conservation of Bonin Islands. Vol. 1 (1969); Vol. 2, 251 pp. (1970). Reviewed by Eldridge, L.G., Atoll Research Bulletin 185: 34-37.
Volume 1 contains article by T. Tuyama on "Flora of the Bonin Islands", pp. 79-110.

Tomich, P.Q. 1965. A question of values. Elepaio 25(7): 54-55.
Concerns program for eradication of rabbits from Manana Island (Hawaiian Is.). "Rabbits have inhabited Manana for more than 60 years and undoubtedly were the greatest factor in the extirpation of nearly all the original vegetation."

Tomich, P.Q. 1969. Mammals in Hawaii. B.P. Bishop Museum Special Publication No. 57.
Concerns introductions of animals which became feral in Hawaii.

Tomich, P.Q. 1972. The feral goat in Hawaii, with particular reference to problems in the national parks, pp. 203-204, in Mueller-Dombois, D., ed. (1972).
The goat is an inharmonious element in native ecosystems and has caused extensive damage, modifications, and also probable extinctions relative to the indigenous flora and fauna.

Tomich, P.Q., Wilson, N. and C.H. Lamoureux. 1968. Ecological factors on Manana Island, Hawaii. Pacific Science 22: 352-368.
Feral rabbits are potent destructive agent on Manana.

Tracey, J.I., et al. 1959. Military Geology of Guam, Mariana Islands. 282 pp. U.S. Army, Chief of Engineers, Intelligence Division, H.Q. US Army Pacific (Tokyo).

Trotman, I.G. 1979. Western Samoa launches a national park program. Parks 3(4): 5-8. Reprinted in Tigerpaper 6(4): 11-14 (1979).
The largest park likely to be established is O Le Pupu - Pu'e National Park in the southern part of Upolu Island, Western Samoa.

Trust Territory of the Pacific Islands. 1972. Rota Master Plan. 93 pp. + 11 Appendices. Planning Division, Department of Public Works, TTPI.
Contains excellent narrative on history of land alteration on Rota (Mariana Is.) from Spanish through German, Japanese, and World War II eras. "The present distribution and nature of the flora represents a mirror of man's activity on the islands and is so artificial as to make it almost impossible to reconstruct the original

climax pattern."

Trust Territory of the Pacific Islands. 1976. Adopted Regulations, Title 45: Fish, Shellfish and Game, Chapter 5: Endangered Species. Territorial Register 2(1): 4 December.
Lists 5 endangered plant species of the Trust Territory: Rock Island Palm, Gulubia palauensis from Palau; Truk Palm, Clinostigma carolinensis from Truk; Palau Palm, Ptychosperma palauensis from Palau; and the Marianas Serianthes, Serianthes nelsonii from Rota.

Tuoc, L.T. 1983. Some thoughts on the control of introduced plants. Noticias de Galapagos 37: 25-26.
Too little has been achieved in checking the spread of introduced plants from the colonized areas (of human habitation and agriculture) into the Galapagos National Park.

Turner, J.S., Smithers, C.N. and R.D. Hoogland. 1968. The Conservation of Norfolk Island. 41 pp. Australian Conservation Foundation, Special Publication No. 1.
Compares Philip I., devastated by feral grazers, to Norfolk I. which has representative remaining plant communities likely to be threatened by recent developments (airstrip, hotels).

Tuttle, M.D. 1986. Gentle fliers of the African night. National Geographic 169(4): 540-558.
Vegetarian bats ("flying foxes") are vital seed-dispersal agents for the regeneration of forests. They are often wrongfully decimated as crop-destroying pests and food-animals, and their decline could have a devastating effect on tropical ecosystems in Samoa, Fiji, Guam, and Saipan where they are declining. Also, three continents support flying foxes that are likewise important for forest regeneration.

Tuyama, T. 1953. On the phytogeographical status of the Bonin and Volcano Islands. Proc. Seventh Pacific Science Congress 5: 208-212.
Owing to the dense population and the inadequate forestry administration, the original forest of the Bonin Group was mostly destroyed. The tall forests which maintain the original features are seen only in restricted areas in Peel and Bailey Islands.

Uhe, G. 1974. Medicinal plants of Samoa. Economic Botany 28(1): 1-30.
154 species are covered in this preliminary survey, a forerunner of more detailed studies of specific plants and remedies.

Umpingco, N.R. 1975. The realities facing Guam today, pp.

107-114, in Force, R.W. and B.P. Bishop, eds., The Impact of Urban Centers in the Pacific. 362 pp. Honolulu, Hawaii: Pacific Science Association.
Guam remains a favorite tourist destination, especially favored by Japanese honeymooners, and the growing economy adversely impacts on the environment, including the systematic destruction of pristine lands.

U.S. Army, Office of the Engineer, Intelligence Division. 1955. Military Geology of Saipan, Mariana Islands. Volume 1. Introduction and Engineering Aspects. 67 pp. H.Q. US Army Forces Far East.
"The vegetation of Saipan has been so altered by burning, cultivation, and importation of foreign species that it is difficult for any but the skilled botanist to know what plants are indigenous and which introduced."

U.S. Army, Office of the Engineer, Intelligence Division. 1956. Military Geology of Palau Islands, Caroline Islands. 285 pp. Tokyo: H.Q. US Army Pacific.
Describes World War II damage to terrain; soil deficiencies; occurrence of bauxite.

U.S. Civil Administration of the Ryukyu Islands. 1953. Ryukyu Islands Forest Situation. 123 pp. USCAR, Special Bulletin No. 2.
Clearing of the forests is a major problem in the Ryukyus. Other threats to native vegetation include the effects of burning, grazing, introduced timber trees, and exploitation of cycads for starch in the "Cycad Hell" of Amami Oshima.

U.S. Department of the Interior, Fish and Wildlife Service. 1968. Hawaii's Endangered Wildlife. 16 pp. Portland, Oregon.
Demonstrates interdependence of endangered vegetation (as habitat) and fauna (especially birds) affected by grazing of rabbits and other animals. Also illustrates how a housing development erected on a pond destroyed a waterbird marsh.

U.S. Department of the Interior, Fish and Wildlife Service. 1970. Hawaii's Endangered Forest Birds. 30 pp. Portland, Oregon.
Demonstrates dependence of specialized native birds on intact, vegetated habitats, i.e., the survival of bird species is linked to preservation of large tracts of native forest. Exotic plants in Alakai Wilderness Preserve (Kauai) threaten the Hawaiian crow; feral goats in Lanai forests threaten the Lanai thrush; grazing rabbits on Laysan Island caused extinction of the Laysan apapane bird; and feral browsing mammals threaten liwi birds on Molokai.

U.S. Navy. 1946. Field survey of Japanese defenses on Chichi Jima Retto. Part One: The Report. CINCPAC - CINCPOA Bulletin 2-46: 1-114.
Useful to researchers wishing to date the changes in vegetation due to military operations.

U.S. War Department, Historical Division. 1946. The Capture of Makin (20 November - 24 November 1943). 135 pp. Washington, D.C.
Includes photos depicting effects of war activities on the vegetation.

VanBalgooy, M.M.J. 1971. Plant-Geography of the Pacific. Blumea Supplement Volume VI. 216 pp. Rijksherbarium, Leyden, The Netherlands.
Contains separate discussions of the composition, including endemism, of the floras of 36 prominent island groups of the Pacific.

VanBalgooy, M.M.J. 1973. Chapter 14. Vascular plants: the altitudinal range of some taxa, pp. 171-175, in Costin, A.B. and R.H. Groves, eds. (1973).
Many plants (mostly at the generic level) which occur in both the Pacific islands and Malesia show two tendencies: "the same taxa occur at lower altitudes in the Pacific than in Malesia; and the total altitudinal range in the Pacific is in general narrower than in Malesia...In the Pacific the impact of man on the original vegetation is greatest in the lowlands, to which many taxa are restricted. Therefore it is particularly important that lowland areas receive high priority in conservation."

Van der Poel, C.J. 1975. Human and cultural values on Guam in a period of rapid transition, pp. 327-336, in Force, R.W. and B. Bishop, eds., The Impact of Urban Centers in the Pacific. 362 pp. Honolulu, Hawaii: Pacific Science Association.
Guamanian young people feel they are becoming second-class citizens in their own country, and are more disturbed than the entrenched older persons about situations such as the presence of military forces on the island; the fact that so much arable land is utilized for roads, hotels and factories; and the breaking up of the forested coastline to build hotels. Their concerns are significant because, as explained by R.W. Force (loc. cit., pp. 345-362), "Much of the credit for the consciousness that exists in the world today about our environment, what is happening to it, and what is happening to man as part of that environment, may be awarded quite legitimately to young people, who sometimes seem to have more respect for the world and its inhabitants than do some of us who are a bit older." Force further observes that Pacific "people are not

museum populations, nor do they wish to be."

Van der Werff, H.H. 1978. The Vegetation of the Galapagos Islands. 102 pp. + 12 plates. Ph.D. thesis, University of Utrecht. Zierikzee, The Netherlands: Drukkerij Lakenman & Ochtman.
Includes new records of pantropical weed introductions, e.g. Tridax procumbens on Santa Cruz; and Pangola grass, Digitaria procumbens, on Santa Cruz where it easily escapes from cultivation as a forage grass and threatens to overrun the native vegetation in the fern-sedge zone by means of vegetative reproduction.

Van der Werff, H.H. 1979. Conservation and vegetation of the Galapagos Islands, pp. 391-404, in Bramwell, D., ed., Plants and Islands. London and New York: Academic Press.
Review of the problems besetting the Galapagos.

Van der Werff, H.H. 1982. Effects of feral pigs and donkeys on the distribution of selected food plants. Noticias de Galapagos 36: 17-18.
Differences in distributions of the orchids Liparis and Prescottia on Santa Cruz I. and Alcedo I. (Galapagos) are probably a result of feral pigs who dig up and eat the subterranean organs of the plants.

Van Tilburg, J. 1987. Symbolic archaeology on Easter Island. Archaeology 40(2): 26-33.
Includes brief discussion of early deforestation by original inhabitants of Easter Island.

Veillon, J.M. 1971. La flore Neo-Caledonienne, son originalite, sa vulnerabilite face aux problemes de degradation et de pollution. Commission du Pacifique Sud, Colloque Regional sur la Protection de la Nature - Recifs et Lagons, Noumea, 4-14 Aout 1971, SPC/RSCN WP. 23 (633/71), pp. 1-5.
In New Caledonia, the relictual, highly endemic flora is exposed to the dangers of destruction through mineworks, roads, and mineral discharges. From review by Plessis, J. Cahiers du Pacifique 16: 213-214 (1972).

Vietmeyer, N. 1986a. Casuarina: weed or windfall? American Forests 92(2): 22-25, 63.
Casuarina, or "Australian pine", grows vigorously in places such as the toxic alumina soils of New Caledonia. This article discusses the potential of Casuarina in reforesting barren lands in developing countries.

Vietmeyer, N. 1986b. Lesser-known plants of potential use in agriculture and forestry. Science 232: 1379-1384.
Several underexploited leguminous tree species are presented as "important weapons" against deforestation in tropical areas. Creating the most enthusiasm is Leu-

caena leucocephala, a fast-growing, nitrogen-fixing tree that promises to provide wood and reforestation for much of the tropics. Experimental plots of leucaena are being grown by the University of Hawaii at Waimanalo, on the island of Oahu.

Villa, J.L. and A. Ponce. 1982. Islands for people and evolution: The Galapagos, pp. 584-587, in McNeely, J.A. and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society. Washington, D.C.: Smithsonian Institution Press.
Suggests ways to orient the management of Galapagos National Park towards the achievement of rural development objectives which benefit people living in the area.

Villiers, A. 1971. Captain Cook: the man who mapped the Pacific. National Geographic 140(3): 297-373.
Background information on major discoveries of land in the Pacific, in non-technical presentation.

Virot, R. 1951a. Associations vegetales de la Nouvelle-Caledonie et leur protection. Journal Societe Oceanistes 7: 263-269.
Plea for judicious control of mineral prospecting, forest exploitation, and other activities which negatively impact the vegetation of New Caledonia.

Virot, R. 1951b. Les plantes indigenes utiles de la Nouvelle-Caledonie. Rev. Intern. Bot. Appliquee no.339-340 (Jan.-Feb. 1951, XII): 120-131.
An attempt to inventory useful plants of New Caledonia, including the endemic medicinal plants Gardenia aubreyi, Gardenia urvillei and Nicotiana fragrans.

Virot, R. 1954. Le probleme de la protection de la nature en Nouvelle-Caledonie. Eighth Congr. Intern. Bot. Rapp. Comm. 21-27: 14-144.
Discusses human threats to vegetation of New Caledonia and conservation procedures to counteract them.

Virot, R. 1956. La vegetation Canaque. Memoires Museum National Histoire Naturelle, serie B. Botanique, 7: 1-398. (Th. Sc. Nat. Paris, 1956, ser. A, no. 736).
Invasions of weeds and other current and future modifications to the vegetation of New Caledonia are discussed. Extensive Bibliography of New Caledonian flora included.

Vogl, R.J. 1971. General ecology of northeast outer slopes of Haleakala Crater, East Maui, Hawaii. Contr. Nat. Cons. 6: 1-8.
Preservation of the slopes is recommended.

Vogl, R.J. and J. Henrickson. 1971. Vegetation of the

alpine bog on East Maui, Hawaii. Pacific Science 25(4): 475-483.
Grazing by feral goats, pigs and cattle may have eliminated Lobelia and/or Argyroxiphium species that may have once existed in the bog.

Wace, N.M. 1960. The botany of the southern oceanic islands. Proceedings of the Royal Society B152: 475-490.
These highly impoverished floras are extremely vulnerable to competition from continental species introduced by man. The native floras have few or no annual species to exploit the open habitats produced by the destruction of the vegetation. The Juan Fernandez Is. are within the scope of this article.

Wace, N.M. 1978. The Character of Oceanic Islands and the Problem of Their Rational Use and Conservation. Morges, Switzerland: IUCN.
Energy flow models are presented for island ecosystems.

Wace, N.M. and M.W. Holdgate. 1976. Man and Nature in the Tristan da Cunha Islands. IUCN Monograph No. 6. 114 pp. Morges, Switzerland: IUCN.
Oceanic islands will have increasing significance as baseline monitoring sites, e.g., a station at Mauna Loa, Hawaii, monitors atmospheric carbon dioxide levels. (Tristan da Cunha, the principal subject of this article, is in the Atlantic Ocean.)

Wagner, J.P. 1985. The "scandalwood". Hawaii 2(2) (Issue No. 4): 51-52.
Story of the 30-year (1800-1830) Hawaiian sandalwood trade, from which the trees are only now slowly reviving. By the 19th century, the original non-Hawaiian resources of sandalwood had dried up through a lack of conservation measures in India, Java, Timor and the East Indies. The Hawaiian aristocracy mortgaged the economy of the islands with promissory notes payable in sandalwood, with disastrous results on the native vegetation.

Wagner, W.H. 1950. Ferns naturalized in Hawaii. B.P. Bishop Museum, Occasional Papers 20(8): 95-121.
Interesting historical data on the establishment of invasive fern species which became naturalized in the Hawaiian Islands, e.g. Azolla filiculoides and Blechnum occidentale.

Wagner, W.H. 1981. Ferns in the Hawaiian Islands. Fiddlehead Forum 8(6): 43-44.
Many ferns were introduced into Hawaii for commercial purposes, e.g. Adiantum cuneatum, Pteris vittata, Ceratopteris thalictroides, and Pityrogramma calomelanos. Apparently extinct ferns of Hawaii include Botrychium

subbifoliatum, Asplenium leucostegioides, and *Diellia mannii*.

Waimea Arboretum and Botanical Garden. 1983. *Checklist of Hawaiian Endemic, Indigenous, Food Plants and Polynesian Introductions in Cultivation in Hawaii.* 31 pp. Waimea Arboretum Foundation Educational Series No. 2. Haleiwa, Hawaii: Waimea Arboretum Foundation.
Includes numerous endangered and threatened Hawaiian species, growing at 16 garden sites.

Walker, C.M. 1971. *Forest Conservation Research Plan for the Seventies.* 35 pp. Honolulu, Hawaii: Department of Land and Natural Resources, Division of Forestry.
Discusses ways in which the ecological basis for understanding forest conservation in Hawaii must be strengthened, and considers the impact of invasive plant species and feral sheep.

Walker, E.H. 1952. A botanical mission to Okinawa and the Southern Ryukyus. *Asa Gray Bulletin*, n.s. 1 (3): 225-244.
Records the northernmost occurrence in the world of the useful nipa palm, *Nipa fruticans*, at Hinai Bay, Iriomote Island, Ryukyus. Also includes many observations, on all the Ryukyus, of invasive weeds and reversions of grassland and agricultural land to forests.

Walker, E.H. 1953. Botanizing with the Okinawans. *The Smithsonian Report for 1952*, pp. 359-383. Washington, D.C.: Smithsonian Institution.
One-third of Okinawa I. (Ryukyus) was devastated in the World War II invasion of 1945. Regarding the barren appearance of the southern end due to the paucity of trees: "Those (trees) that the Japanese army did not use in building defenses, the Americans blew down to eliminate snipers...The appearance of barrenness is further augmented by the American installations built on great bulldozed and leveled areas, once hills and valleys covered with grass, trees, or cultivated fields."

Walker, E.H. 1957. A sketch of the vegetation and plants of the Southern Ryukyu Islands. *Proc. Eighth Pacific Science Congress* 4: 397-406.
On southern Okinawa Island, long occupation and destruction by World War II have swept away most of the arboreal cover, leaving extensive areas grown up in coarse grasses such as *Miscanthus floridulus* and "lalang" (*Imperata cylindrica* var. *koenigii*).

Walker, F.S. 1962. *The Forests of the British Solomon Islands Protectorate.* 186 pp. Honiara, Guadalcanal: South Pacific Commission. (Reprint of 1948 Original).
Details of extensive secondary vegetation on various islands are included.

Walker, R.L. 1969. Staff report by State Division of Fish and Game on question: Should axis deer be introduced to the Island of Hawaii. Elepaio 30(4): 31-36.
Division of Fish and Game recommends introduction of axis deer to island of Hawaii, after reviewing 18 harmful effects such action may cause; indirectly provides excellent insight into bureaucratic mentality.

Wallace, R., *et al.* 1973. Chapter 6. The enigma of a tree, pp. 150-163, in The American Wilderness Series: Hawaii. New York: Time-Life Books.
Concerns *Hibiscadelphus distans* (Malvaceae).

Wallis, O.L. 1961. Coral Reefs, A Challenge to Conservation. 24 pp. mimeo. Paper presented at Sixth International Game Fish Conference, Miami Beach, Florida, 1961. Washington, D.C.: U.S. Department of the Interior, National Park Service.
Among the eleven stated categories of impact to the fragile ecosystems of coral reefs is "changes wrought on land". Massive land-clearing can cause water run-off into coral beds, silting them up. Bibliography of 46 references.

Walsh, J. 1976. Superport for Palau debated: ecopolitics in the Far Pacific. Science 194(4268): 919-921.
The possibility that a superport for transshipping Iranian oil to Japan may be built in Palau, causes concern for resource development in the ecologically fragile lagoon and reef of Palau. Also mentions incipient cultural deterioration which may ensue due to infusion of more money and material possessions to Palauans at such a superport.

Ward, R.G. 1965. Land Use and Population in Fiji: A Geographical Study. 309 pp. Department of Technical Cooperation, Overseas Research Publication No. 9. London: Her Majesty's Stationery Office.
Relates intensive utilization of terrestrial resources due to increasing population pressure.

Wardle, P., Moar, N.T. and D.R. Given. 1978. Goats on Auckland Islands. New Zealand Journal of Botany 16(2): 291-292.
Instructive for its approach to the feral goat problem, though Auckland Is. are not covered by the present Bibliography. See Campbell, D.J. and M.R. Rudge (1978) for rebuttal article.

Warner, R.E. 1960. A forest dies on Mauna Kea. Pacific Discovery 13(2): 6-14.
On the island of Hawaii, feral sheep have destroyed natural vegetation in the "mamane" forest dominated by

Sophora chrysophylla, on the upper slopes of Mauna Kea volcanic peak. Graphically illustrated with photos.

Warner, R.E. 1961a. The problem of native forest destruction in Hawaii. Tenth Pacific Science Congress, Abstracts, 251-252.
Short notes on aspects of Hawaiian deforestation.

Warner, R.E. 1961b. Hawaii's birds: birth and death of an island biota. Pacific Discovery 14(5): 6-13.
Photos show effects, on vegetation and forests, of feral sheep and other stock, overbrowsing, overgrazing, trampling, erosion; bulldozing natural vegetation for macadamia nut orchards.

Warner, R.E. 1963. Recent history and ecology of the Laysan duck. The Condor 65(1): 3-23.
Details the effects of destruction of the Laysan duck's habitat by overgrazing rabbits, pigs and Guinea pigs. "The nearly completed annihilation of the flora of Laysan Island followed the introduction of domestic rabbits in 1903 to provide meat for guano miners."

Warner, R.E., ed. 1968. Scientific Report of the Kipahulu Valley Expedition. 184 pp. The Nature Conservancy.
Contains numerous observations on status and threats to natural vegetation of the Kipahulu Valley, Hawaii, by expedition participants R.E. Warner, R.E. DeWreede, C.H. Lamoureux, and G.A. Smathers.

Warshauer, F.R. 1977. The Kalapana extension of Hawaii Volcanoes National Park: its variety, vegetation, and value. Newsletter Hawaiian Botanical Society 16(3-4): 57-60.
Severe problems with feral pigs are delineated.

Warshauer, F.R. and J.D. Jacobi. 1982. Distribution and status of Vicia menziesii Spreng. (Leguminosae): Hawaii's first officially listed endangered plant species. Biological Conservation 23(2): 111-126.
"The primary factors responsible for the decline of V. menziesii are habitat loss and excessive predation on the plants by introduced ungulates. Continued logging and cattle grazing within its remnant range are major threats to its existence."

Watson, J.S. 1961. Feral rabbit populations on Pacific islands. Pacific Science 15(4): 591-593.
Discusses rabbit damage to vegetation, and causes of rabbit population fluctuations, in the Hawaiian Leeward Islands of Lisianski and Laysan; Phoenix I., Philip I., and islets of the main Hawaiian group: Manana, Lehua and Molokini.

Watson-Gegeo, K.A. 1982. Review of Bryan Farrell, Hawaii, The Legend That Sells. Honolulu: University of Hawaii Press, 1982. 420 pp. Pacific Studies 6(1): 128-132.
Farrell's book is "the first comprehensive treatment of tourism development in Hawaii", with a chapter on the impact of tourism on the physical landscape indicating that "the negative impacts on land and shore have been coral reef destruction, problems of beach access for local people, overstressing of energy and water resources, and destruction of local vegetation and soil."

Watters, R.F. 1960. The nature of shifting cultivation: a review of recent research. Pacific Viewpoint 1: 59-99.
Impact of shifting cultivation in Fiji and Samoa.

Watts, D. 1970. Persistence and change in the vegetation of oceanic islands: an example from Barbados, West Indies. Canadian Geographer 14(2): 91-109.
Evidence from the Caribbean island of Barbados strengthens the view that the position of plant aliens in local (indigenous) vegetation associations is an artificial one, in that as soon as felling or grazing activities are reduced in scale, native species usually regain their pre-eminence. Statistics from Pacific islands are included for comparison.

Weaver, K.F. 1971. Maui, where Old Hawaii still lives. National Geographic 139(4): 514-543.
Includes mention of the silverswords (Argyroxiphium) of Haleakala Crater.

Weber, D. 1971. Pinta, Galapagos: une ile a sauver. Biological Conservation 4(1): 8-12.
Efforts to salvage the ecosystems of Pinta I. in the Galapagos Islands of Ecuador.

Weber, W.A. 1986. The lichen flora of the Galapagos Islands, Ecuador. Mycotaxon 27: 451-497.
Includes discussion of catastrophic losses of lichen habitats in the Galapagos caused by the El Nino phenomenon of 1982-1983.

Weber, W.A., Gradstein, S.R., Lanier, J. and H.J.M. Sipman. 1977. Bryophytes and lichens of the Galapagos Islands. Noticias de Galapagos 26: 7-11.
Differences in the bryophyte assemblages on each island in the Galapagos may be due in part to the influence of man and his cattle. Suggests protection of San Cristobal permanent streams in view of unique bryophyte flora there.

Webster, G.L. 1951. The Polynesian species of Myoporum. Pacific Science 5(1): 52-77.

"The real value of Myoporum to the Hawaiian Islands resides in its role in the formation of a dry forest cover and in the consequent checking of soil erosion. On most of the islands the dry forest region has been partially or completely denuded, with serious consequent erosion."

Weimarck, G. 1984. Conservation work with Sophora toromiro, the tree of Easter Island. Reports from the Botanical Institute, University of Aarhus No. 10: 40-42.
The toromiro tree, "virtually eradicated" from Easter Island, now exists only as three specimens in Goteborg Botanical Garden, grown from seeds collected by Thor Heyerdahl from the last surviving tree in 1955, which is now dead (having been gradually cut down for the wood used for sculptures). Attempts have been made to reintroduce the species to Easter Island.

Weller, D. 1981. A Preliminary Look at Some Environmental Effects of the U.S. Nuclear Weapons Testing Program in the Marshall Islands. 20 pp. Unpublished manuscript. San Jose, California.
Includes consideration of effects of nuclear device detonation on igniting the vegetation, soil radionuclide uptake by plants (radioactivity), and destruction of surface soil.

Wells, S.M. 1985. The IUCN Directory of Coral Reefs of International Importance. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 298. (Abstract)
Objectives include to provide a broad survey of the world's reefs in sufficient detail to enable priorities for reef conservation to be established at both national and international levels."

Wenkham, R. 1967a. Importance to the people of Hawaii of conservation of natural scenic resources. Newsletter Hawaiian Botanical Society 6 (1 & 2): 1-5.
Instances of alleged carelessness towards Hawaiian natural environment are enumerated.

Wenkham, R. 1967b. A Kauai national park. National Parks Magazine 41(234): 4-8.
97,000 acres (150 square miles) of shoreside cliffs and wilderness interior are proposed for preservation on Kauai (Hawaiian Is.), including Waimea Canyon, Napali Cliffs, and Alakai Swamp.

Wenkham, R. 1971. Micronesian parks: a propsal. Micronesian Reporter 19(3): 9-22.
Descriptions and photos of natural areas being proposed for parks.

Wenkham, R. and K. Brower. 1975. Introduction: towards

oceanic parks for Micronesia - a proposal, pp. 10-25, in Brower, K., Micronesia: Island Wilderness. 161 pp. San Francisco, California: Friends of the Earth.
Discusses conservation benefits that would accrue from proposed oceanic parks on Nan Madol (Ponape), Elabaob (Palau Is.), Peleliu (Palau Is.), Arno Atoll (Marshall Is.), Marpi (Saipan, Marianas), Truk Lagoon, and Guam.

Wentworth, C.K., Mason, A.C. and D.A. Davis. 1955. Salt-water encroachment as induced by sea-level excavation on Angaur Island. Economic Geology 50(7): 669-680.
Phosphate mining on Angaur I. (Palau Is.) produced excavations below sea level in which lakes were formed, and contamination of freshwater supplies and of agricultural land by salt water resulted from tidal pulsations through the fissured rock.

Westendorp, F.J. van. 1961. Agricultural development on Niue. South Pacific Bulletin 11(2): 67-69.
Photos include: "Part of the "Niue desert", an area of 8,100 acres which because of wrong use in the past, including frequent burning off, became valueless for agricultural purposes."

Wester, L. 1978. Development of the Adventive Flora of the Hawaiian Islands. 13 pp. Paper prepared for 74th Annual Meeting of the Association of American Geographers, New Orleans, April 1978.
Discusses alternative explanations that may account for the recent decline in the rate of arrival of introduced plants. A preliminary survey indicates there are at least 600 adventive plant species in Hawaii.

Wester, L.L. and H.B. Wood. 1977. Koster's curse (Clidemia hirta), a weed pest in Hawaiian forests. Environmental Conservation 4(1): 35-41.
A plant of the melastome family, which smothers extensive areas of indigenous vegetation.

Whistler, W.A. 1976. Inventory and Mapping of Wetland Vegetation in the Territory of American Samoa. 74 pp. U.S. Army Corps of Engineers, Pacific Ocean Division, Fort Shafter.
Aunu'u Crater marsh, Pala Lagoon, and the mud lake on Aunu'u with its mangrove forest, are recommended for nature preserves. Samoan localities of Xylocarpus moluccensis should be protected.

Whistler, W.A. 1978. Vegetation of the montane region of Savai'i, Western Samoa. Pacific Science 32(1): 79-94.
Includes discussion of proposal to establish a national park in the Mt. Silisili area, which supports many endemic plant species.

Whistler, W.A. 1980. The vegetation of Eastern Samoa. Allertonia 2(2): 45-190.
Includes discussion of 4 types of disturbed vegetation: managed land; kula (Dicranopteris) fernland; disturbed forest; and Rhus secondary forest. In general, "approximately one-third of the area (of Eastern Samoa) is covered by plantation and another third by secondary forest."

Whistler, W.A. 1981a. A naturalist in the South Pacific: off the beaten track in Samoa. Bulletin Pacific Tropical Botanical Garden 11(1): 1-6.
Various proposals to erect a hotel on Nu'utele ("an inviable project") and to raise goats on the islands to provide export goat meat for Fiji, have caused the rare vegetation to "remain under the sword of Damocles".

Whistler, W.A. 1981b. A naturalist in the South Pacific: north to Tokelau. Bulletin Pacific Tropical Botanical Garden 11(2): 29-37.
Observing rare plants such as Hedyotis romanzoffianus on Atafu, and newly introduced weeds such as Lepidium virginicum on Nukunono.

Whistler, W.A. 1982. A naturalist in the South Pacific: in search of the apetahi. Bulletin Pacific Tropical Botanical Garden 12(1): 1-4.
The "apetahi" is Apetahia raiateensis, a woody lobelioid endemic to Temehani Mountain on Raiatea (in Leeward Society Is.). The plant is seriously threatened by flower pickers especially during celebrations such as the Bastille Day fete in mid-July, when masses of its flowers are picked for sale in town.

Whistler, W.A. 1983a. The flora and vegetation of Swains Island. Atoll Research Bulletin 262: 1-25.
Swains is politically in the Territory of American Samoa. "The vegetation of Swains Island is greatly disturbed and nearly the whole island is covered with coconut palms. It is doubtful if any of the original forest vegetation remains."

Whistler, W.A. 1983b. Vegetation and flora of the Aleipata Islands, Western Samoa. Pacific Science 37(3): 227-249.
Condition of the vegetation is observed.

Whistler, W.A. 1984. Annotated list of Samoan plant names. Economic Botany 38(4): 464-489.
Useful adjunct to other articles on Samoa by Whistler.

Whistler, W.A. 1983c. Weed Handbook of Western Polynesia. 152 pp.
Weed control has become very important as the trend to increase food crop production continues in Polynesia.

White, K.J. 1965. Forestry activity (in the Territory of Papua and New Guinea). South Pacific Bulletin 15(2): 31-34.
Mentions reafforestation at Kerauat, near Rabaul (New Britain) with native hoop and klinkii pine (Araucaria cunninghamii, A. hunsteinii) and teak (Tectona grandis).

Whiteaker, L.D. 1983. The vegetation and environment of the Crater District of Haleakala National Park. Pacific Science 37(1): 1-24.
Exotic plant "introductions have resulted in native species losing ground to invading forms, and there has been up to 100 percent alteration in species composition in some areas."

Whitesell, C.D. 1964. Silvical Characteristics of Koa (Acacia koa Gray). 12 pp. U.S. Forest Service Research Paper, PSW-16.
Forests of koa, the most valuable common native timber species in Hawaii, have been reduced by land clearing, poor cutting practices, and destruction by animals, insects, and fire.

Whitesell, C.D. 1972. Natural areas on Guam. Newsletter Hawaiian Botanical Society 11(1): 7.
"The best residual forests on Guam are on the Naval Magazine, and on Andersen Air Base, protected by the military."

Whitesell, C.D. 1974. Tree plantings on Kahoolawe. Newsletter Hawaiian Botanical Society 13(2): 4-5.
Describes trial plantings for purposes of reforesting, on a Hawaiian island said to have no soil, only parent material (bare rock).

Whitesell, C.D. and M.F. Landgraf. 1966. Growing Queensland maple on lava rocklands in Hawaii. Tree Planters' Notes No. 77: 1-3.
"Thousands of acres of rough or "aa" lava rockland now support low-value species, but this land can produce valuable stands of timber." On two and one-half acres in the Waiakea Forest Reserve (Island of Hawaii), the Queensland maple trees, Flindersia brayleana, were planted after most of the native ohia vegetation was knocked down and crushed by bulldozers in preparation. Growth of the Queensland maple was "impressive".

Whitmore, T.C. 1966. The social status of Agathis in a rain forest in Melanesia. Journal of Ecology 54: 285-301.
Details the status of the kauri, A. macrophylla, in forests of Vanikoro Island, as well as in deforested and forest-managed areas of the island.

Whitmore, T.C. 1969. The vegetation of the Solomon Islands. Philosophical Transactions, Royal Society B255: 259-270.

"The extensive areas which carry thickets of small trees and climber tangles instead of high forest are thought due to the combined influence of man, earthquake, landslip and cyclone."

Whitmore, T.C. 1976. Conservation Review of Tropical Rainforests: General Considerations and Asia. 116 pp. IUCN-UNEP, WWF Switzerland.

Includes general account of Fiji, Micronesia, Polynesia, New Hebrides.

Whitmore, T.C. 1980. Utilization, potential, and conservation of *Agathis*, a genus of tropical Asian conifers. Economic Botany 34: 1-12.

Agathis includes the kauri, *A. macrophylla*, of Melanesia.

Whitney, L.D., Hosaka, E.Y. and J.C. Ripperton. 1939 (Reprinted 1964). Grasses of the Hawaiian Ranges. 148 pp. Hawaii Agricultural Experiment Station Bulletin No. 82.

Useful discussions of introduced, aggressive weedy and potentially weedy grasses are included, e.g. ripgut grass (*Bromus rigidus*), barbwire grass (*Cymbopogon refractus*), and Kikuyu grass (*Pennisetum clandestinum*).

Wichman, C. 1978. Limahuli Valley botanical survey. Bulletin Pacific Tropical Botanical Garden 8(1): 1-6.

The PTBG's new satellite garden on fairly wild land harbors two apparently new color forms of the endemic (on Kauai) and rare *Hibiscus saintjohnianus*, and other novelties.

Wiens, H.J. 1955. The Geography of Kapingamarangi Atoll in the Eastern Carolines. 94 pp. SIM Report No. 21. Washington, D.C.: Pacific Science Board, National Research Council.

The atoll comprises 33 vegetated islets which support creeping vines such as *Cassytha*, *Vigna* and *Ipomoea*, which choke out native vegetation. "The high degree of manipulation of the vegetation by man obscured the natural vegetation succession...it was very difficult to interpret the natural ecology and environment from the apparent patterns."

Wiens, H.J. 1957. Field notes on atolls visited in the Marshalls, 1956. Atoll Research Bulletin 54: 1-23.

The islets visited on Kwajelein Atoll had been violently disturbed by World War II military operations and the vegetation was thus quite abnormal. War damage to vegetation is apparently the major factor in weed invasion and spread on Majuro Atoll.

Wiens, H.J. 1962. Atoll Environment and Ecology. 532 pp. New Haven, Connecticut: Yale University Press.
Includes discussions of plants introduced and maintained by man on atolls (Chapters 16 & 17), and of population pressures on atoll resources.

Wiggins, I.L. 1966. Origins and relationships of the flora of the Galapagos Islands, pp. 175-182, in Bowman, R.I., ed., The Galapagos. Berkeley and Los Angeles: University of California Press.
Good background relating to endemic flora.

Wiggins, I.L. and D.M. Porter. 1971. Flora of the Galapagos Islands. 998 pp. Stanford, California: Stanford University Press.
Includes information on patterns of human settlement in the Galapagos, with attendant agricultural expansion, goat problems, and encroachment into natural forests.

Williams, M. and B. Macdonald. 1985. The Phosphateers. 586 pp. Carlton, Victoria, Australia: Melbourne University Press.
An account of the British Phosphate Commissioners, including reference to extensive phosphate mining on Nauru, Banaba (Ocean I.), Makatea (Tahiti), as well as Christmas I. (Indian Ocean); considerations of land rehabilitation.

Wills,R. 1965. Tourism for Guam. South Pacific Bulletin 15(3): 44-45, 58.
"The coconut palm is predominant and much of the jungle area is covered with a thick green mantle of tangan tangan, *Leucaena glauca*, which is used extensively for animal fodder and fuel."

Wilson, P.T. 1976. Conservation problems in Micronesia. Oceans 9(3): 34-41.
Aspects of a number of serious Micronesian questions are elaborated.

Wirawan, N. 1974. Floristic and Structural Development of Native Dry Forest Stands at Mokuleia, N.W. Oahu. Island Ecosystems IRP/IBP Hawaii, Technical Report No. 34. 56 pp. Honolulu, Hawaii: University of Hawaii.
Introduced *Schinus* suppresses native *Canthium*, and introduced *Melinis* grass suppresses seedling establishment of *Erythrina sandwicensis*, but native *Sapindus* is able to invade stands of introduced *Leucaena*.

Wodzicki, K. 1970. Man and his animals. New Zealand Science Review 28(5): 89-102.
Includes a quotation from Quentin Thomas regarding

Hawaii, to the effect that "A choice must be made between managing the native flora and fauna out of existence by an increasing encroachment upon natural or semi-natural areas, or of wisely conserving specific elements of it under a well-defined plan."

Wodzicki, K. 1971. The birds of Niue Island, South Pacific: an annotated checklist. Notornis 18(4): 291-304.
"During the last century the shifting system of agriculture with repeated burning of second-growth forest has led to the establishment of large "fern-land areas" and to a considerable reduction of the primeval, tropical forest that once covered the whole island. This must have significantly affected all (bird) species that solely or partly depend on the fruit or seeds of forest trees or require tall forest community with a high canopy for nesting, such as tuaki, taketake, or ngongo.

Wodzicki, K. 1973. Problems of vanishing plants and animals. Proc. Regional Symposium on Conservation of Nature - Reefs and Lagoons, Part II, pp. 217-223.
Includes considerations of rare plants of the South Pacific.

Wodzicki, K. 1981. Some nature conservation problems in the South Pacific. Biological Conservation 21(1): 5-18.
Conservation problems affecting various ecosystems in the South Pacific include: adventive plant and animal species, forest fires, tourism, pollution of mangrove and sea-grass communities, mining, population growth, and milling of indigenous forests. Useful bibliography included.

Wodzicki, K. and M. Laird. 1970. Birds and bird lore in the Tokelau Islands. Notornis 17(4): 247-276.
Man causes vegetational changes such as the planting of coconut palms and other crops, which in addition to the hunting of birds and their eggs, makes him appear to be the most important and efficient negative factor affecting birds on tropical islands.

Womersley, J.S., compiler. 1974. Conservation of primitive, rare, and endangered species, p. 594, in Specht, R.L., et al., eds., Conservation of Major Plant Communities in Australia and Papua New Guinea. 667 pp. Australian Journal of Botany, Supplementary Series, Supplement No. 7.
A period of locally intense agricultural development is commencing in Papua New Guinea and this will mean the destruction of large areas of closed forest, particularly on the north coast of the island of New Britain.

Woodward, P.W. 1972. The natural history of Kure Atoll, Northwestern Hawaiian Islands. Atoll Research Bulletin

164: 1-318.
On Green I., introduced _Verbesina enceliodes_ in the central plain is spreading rapidly and threatening the native plant species, which cannot grow under it. It also threatens the breeding habitat of blue-faced booby birds.

Woolliams, K. 1972a. Propagation of endangered tropical plants. _Bulletin Pacific Tropical Botanical Garden_ 2(1): 17-20.
Lists Hawaiian species being grown in the nursery of PTBG, with cultural notes. A number of subsequent articles entitled "From the Nursery" document additional species being cultivated there.

Woolliams, K. 1972b. A report on the endangered species. _Bulletin Pacific Tropical Botanical Garden_ 2(3): 46-49.
Data on 12 Hawaiian endangered plants being propagated in Garden nursery.

Woolliams, K.R. 1974a. Plant collecting trip to the Ogasawara Islands. _Bulletin Pacific Tropical Botanical Garden_ 4(2): 23-28.
The Ogasawara Islands flora comprises at least 400 species, of which 46 percent is endemic. Hahajima I. has endangered _Erythrina boninensis_. On Minamijima I. all goats were exterminated in 1972 and the vegetation has since somewhat regenerated. The handsome palm _Clinostigma savoryanum_ occurs on Chichijima I., where its population was reduced to 100-200 plants during World War II: the young growing tips served as a food source. The _Clinostigma_ is now threatened since rats eat and destroy its seeds, making regeneration difficult.

Woolliams, K.R. 1974b. Endangered species now established in the grounds of Pacific Garden. _Bulletin Pacific Tropical Botanical Garden_ 4(2): 33.
List includes 26 Hawaiian species.

Woolliams, K.R. 1975a. The propagation of Hawaiian endangered species. _Newsletter Hawaiian Botanical Society_ 14(4): 59-68.
Includes specific examples of successes and failures.

Woolliams, K.R. 1975b. Propagation (_Sesbania tomentosa_). _Notes Waimea Arboretum_ 2(2): 7-8.
Cultivation of an endangered Hawaiian legumes.

Woolliams, K.R. 1975c. Plant collecting in the Ogasawara Islands. "Collecting and Breeding". _Institute of Breeding Research (Tokyo)_ 37(7). (In Japanese)
Emphasizes indigenous plants of Chichijima and Minamijima islands.

Woolliams, K.R. 1976a. Tentative list of rare and endangered plants of the Ogasawara Islands. Notes Waimea Arboretum 3(2): 10-12.
Several endemics are endangered.

Woolliams, K.R. 1976b. Propagation of Hawaiian endangered species, pp. 73-83, in Simmons, J.B., et al., eds., Conservation of Threatened Plants. New York and London: Plenum Press. (Abstract appears in Notes Waimea Arboretum 2(2): 5.1974.)
The procedures leading to cultivation of rare and endangered Hawaiian plants.

Woolliams, K.R. 1976c. Propagation (Chenopodium pekeloi). Notes Waimea Arboretum 3(1): 5-6.
Cultivation of an endangered Hawaiian chenopod.

Woolliams, K.R. 1978a. Propagation of some endangered Hawaiian plants at Waimea Arboretum. Notes Waimea Arboretum 5(1): 3-4.
Data on Sophora, Mezoneuron, Lepechinia.

Woolliams, K.R. 1978b. Observations on the flora of the Ogasawara Islands. Notes Waimea Arboretum 5(2): 2-10; 6(1): 6-14 (1979).
Data on 18 mostly threatened plant species.

Woolliams, K.R. 1979. Kokia cookei: extinction or survival? Notes Waimea Arboretum 6(1): 2-5.
Precarious existence of endangered Hawaiian plant.

Woolliams, K.R. 1980. Oahu yellow hibiscus found. Notes Waimea Arboretum 7(1): 9, 12.
Concerns Hibiscus brackenridgei var. mokuleiana.

Woolliams, K.R. 1981a. Serianthes nelsonii:an update. Notes Waimea Arboretum 8(1): 8-9.
First discovery of the plant in 1980 on Rota I., near Guam.

Woolliams, K.R. 1981b. Kokia cookei: progress report. Notes Waimea Arboretum 8(1): 8.
K. cookei grafted onto K. drynarioides, in Hawaii.

Woolliams, K.R. 1982. Kokia cookei: more good news. Notes Waimea Arboretum 9(1): 3-4.
Progress of Kokia cookei in cultivation.

Woolliams, K.R. 1983. Ogasawara Islands: news from Hahajima. Notes Waimea Arboretum 10(1): 4-5.
Data on four threatened plant species.

Woolliams, K.R. 1985. Endangered Heliconia: how serious a problem? Notes Waimea Arboretum 12(1): 5-8.

Refers to Fiji.

Woolliams, K., Degener, O. and I. Degener. 1980a. Kokia cookei Deg.: then there were two!. Notes Waimea Arboretum 7(1): 2-7.
Cultivation history of an extremely endangered species.

Woolliams, K., Degener, O. and I. Degener. 1980b. Cooke's kokia again. Notes Waimea Arboretum 7(2): 8-9.
Refers to the endangered Hawaiian Kokia cookei (Malvaceae).

Wright, H.D. 1946. Orchid hunting on Guadalcanal. American Orchid Society Bulletin 15(3): 106-116.
"Much of the northern coast was shorn of vegetation to create huge Lever Brothers Coconut Plantations."

Wylie, R.B. 1924. Notes on introduced plants. Proc. Iowa Academy of Science 30: 333-336.
In the Fiji Islands of 1922, the intolerable nuisance weeds already included the sensitive plant (Mimosa pudica), Para grass (Panicum barbinode), lantana (Lantana camara), guava (Psidium guajava), Mikania scandens, and Koster's curse (Clidemia hirta).

Yates, S. 1984. On the cutting edge of extinction. Audubon 86(4): 62-85.
Deforestation contributes to habitat diminishment of Hawaiian endemic birds.

Yee, R. 1984a. Gardens in time: plants of modern Hawaii. Ka 'Elele 11(2): 4-5.
Discusses introduced plants harmful to Hawaiian ecosystems, e.g. lantana, koa-haole, and banana poka.

Yee, R. 1984b. Dry lowland plants dominate this garden. Ka 'Elele 11(6): 4-5.
In the Hawaiian Is., dry lowland forest contains more endangered species than any other plant community. Plants such as Hibiscus brackenridgei are rare in this rapidly diminishing ecosystem.

Yen, D.E. 1975. Effects of urbanization on village agriculture in Oceania, pp. 171-180, in Force, R.W. and B. Bishop, eds., The Impact of Urban Centers in the Pacific. 362 pp. Honolulu, Hawaii: Pacific Science Association.
It is possible that the depopulation of rural and outer-island areas in Oceania may actually have a beneficial effect on natural resources. When people move to cities and urbanized areas, there is created a "fallowing" period for the land they vacated: land whose topography and soils are best fit for the readaptation of traditional crops and forms of agriculture under a new

economic and political order emanating from the towns.

Yocom, C.F. 1967. Ecology of feral goats in Haleakala National Park, Maui, Hawaii. American Midland Naturalist 77(2): 418-451.
Feral goats may have eliminated native Lobelia and Argyroxiphium species.

Yoshida, A. and T. Tannawa. 1976. Endangered plant species of the Ogasawara Islands. Notes Waimea Arboretum 3(2): 8-9.
Listing of endangered plants from area formerly known also as Bonin Islands.

Young, R.A. and P. Popenoe. 1916. Saving the kokio tree. Journal of Heredity 7(1): 24-28.
Refers to the Hawaiian Kokia drynarioides (Malvaceae).

Younge, O.R. and J.C. Moomaw. 1960. Revegetation of stripmined bauxite lands in Hawaii. Economic Botany 14: 316-330.
Experimental study of devastated lands.

Yuncker, T.G. 1934. Some botanical aspects of the Hawaiian Islands. Torreya 34(2): 29-36.
Includes remarks on unfavorable influences on the native flora, including feral pigs, feral goats, vigorous weeds, sandalwood trade, as well as mentioning beneficial plants for reforestation.

Yuncker, T.G. 1937. Three additional species of Peperomia in Hawaii. B. P. Bishop Museum, Occasional Papers 13(14): 161-165.
In Honolulu (Oahu), Peperomia pellucida is now naturalized and locally common. The species was "probably accidentally introduced from India with plants for reforestation."

Yuncker, T.G. 1945. Plants of the Manua Islands. B.P. Bishop Museum Bulletin 184: 1-73.
In American Samoa, "the original vegetation has now been exterminated to a large extent on the lowlands and lower hillsides to provide for coconut and banana plantations."

Yuncker, T.G. 1956. Plants of Tonga. B.P. Bishop Museum Bulletin 220: 1-283.
On Tonga, some alien plant species "have undoubtedly played a part in limiting or even exterminating some endemics or indigenous species through aggressiveness." Lumber operations on some islands have caused soil erosion problems on slopes.

Zacharin, R.F. 1978. Emigrant Eucalypts: Gum Trees as

Exotics. 137 pp. Carlton, Victoria, Australia: Melbourne University Press.
Background of the often deprecated genus Eucalyptus, used in many reforestation programs in the Pacific.

Zimmerman, E.C. 1948. Island faunas in general: their special interest and vulnerability, pp. 17-18, in Coolidge, H.J., compiler (1948).
The Bishop Museum 1934 Mangareva Expedition found that on Mangareva "all the native forests are gone - burned and reburned, and eaten away by goats...Today on Mangareva, nothing but the ghosts of a once unique and magnificent biota hover - their cries are echoed by the moaning birds screaming over mountain slopes barren of native life and mocked by the bleating of hungry goats."

Zimmerman, E.C. 1963. Nature of the land biota, pp. 57-64, in Fosberg, F.R., ed. (1963).
Notes that many Polynesian islands have been stripped bare by goats, and the lower islands (of 1,000 or 2,000 feet in elevation) that do not have heavy rain forest have been subjected to repeated burning.

Zucker, W.H. 1985. Reef management in the Pacific Region. Proc. Fifth International Coral Reef Congress (Tahiti, 1985) 2: 424.
The South Pacific Regional Environment Programme (SPREP) includes coverage of coastal ecosystem interactions.

SUBJECT INDEX

Index Headings

1. NATURAL ENVIRONMENTAL FACTORS

- 1a. Storms (El Nino, Typhoons)
- 1b. Volcanic Eruptions
- (Ecosystems treated as 5b)

2. INTRODUCED AND FERAL ANIMALS

- 2a. Introduced Animals in General (Including Pigs)
- 2b. Deer (Axis, Blacktail)
- 2c. Goats
- 2d. Rabbits

3. INTRODUCED, INDIGENOUS, AND ECONOMIC PLANTS

- 3a. Endangered and Threatened Plant Species
- 3b. Endemism and Endemic Plants
- 3c. Economic Plants in General (Including Germplasm)
- 3d. Weeds and Other Alien Plants (Trees, Grasses)
- 3e. Eucalyptus
- 3f. Lantana
- 3g. Ferns and Fernlands
- 3h. Sandalwood (Exploitation, Decline, Protection)
- 3i. Medicinal Plants

4. HUMAN IMPACTS UPON SPECIES AND HABITATS

- 4a. Human Disturbances of Vegetation in General
- 4b. Economic Development
- 4c. Population Pressure (Including Urbanization)
- 4d. Agriculture (Activities, Ranching, Land Use)
- 4e. Soil Erosion (Including Soils)
- 4f. Deforestation (Including Timbering)
- 4g. Forestry (Forests, Reforestation, Practices, Resources, Management)
- 4h. Mining (Mineral Exploitation)
- 4i. Nuclear Testing (Detonations, Radioactivity)
- 4j. Tourism
- 4k. World War II (Military Operations and Facilities)

5. CONSERVATION ACTIVITIES AND VALUES

- 5a. Conservation Studies and Problems
- 5b. Ecosystems (Studies, Status, Characteristics, Factors, Vegetation Studies)
- 5c. Nature Reserves (Natural Areas, National Parks)
- 5d. Botanical Gardens (Including Arboreta, *Ex situ* Preservation, Propagation)
- 5e. Ethics of Conservation

SUBJECT INDEX

1. NATURAL ENVIRONMENTAL FACTORS

1a. Storms

Canby, 1984
Fosberg, 1961
Weber, 1986

1b. Volcanic Eruptions

Colinvaux, et al., 1968
Degener & Degener, 1968
Dutton, 1884
Hamann, 1981
Smathers, 1969
Smathers & Mueller-Dombois 1974
Whitmore, 1969

2. INTRODUCED AND FERAL ANIMALS

2a. Introduced Animals in General

Anonymous, 1968, 1986d
Atkinson, 1977
Bakus, 1975
Baldwin & Fagerlund, 1943
Black, 1976
Bryan, 1931
Carlquist, 1982b
Cooray, 1974
Dawson, 1962
Degener & Degener, 1961a, 1971a, 1971d, 1972
Dening, 1982
Duefrene, 1984
Duffy, 1981
Eckhardt, 1972
Egler, 1947
Eliasson, 1968
Elton, 1958
Flanders, 1985
Fosberg, 1936, 1963a
Fowler, 1979
Gardner & Gardner, 1985
Giffin, 1977
Gillett, 1972
Green, 1979
Harrison, 1972
Hartt & Neal, 1940
Herbst, 1977a
Hickman, 1985
Howard, 1965
Jacobi, 1981
Judd, 1916
Kikukawa & LeBarron, 1971
Kirch, 1982a
Koford, 1966
Kramer, R., 1969
Lawesson, 1986
LeBarron, 1971b
Long, 1960
Loope & Stone, 1984
MacCaughey, 1918-1919
Milton, 1968
Mitchell, 1981
Montgomery, 1972
Mueller-Dombois, 1967, 1972
Mueller-Dombois & Krajina, 1968
Mueller-Dombois & Lamoureux, 1967
Mull, M.E., 1977, 1978
Mull, W.P., 1975
Munro, 1952a
Myrhe, 1970
Paramonov, 1963
Perry, 1969
Peterson, D., 1976
Richardson, 1949
Roedelberger & Groschoff, 1967
Sachet, 1963
Sachet, et al., 1975
Spatz & Mueller-Dombois, 1972a
Squire, 1984
Stager, 1964
State Dept. of Natural Resources, 1976
Stoddart, 1965

Stuessy, et al., 1984
Svihla, 1936
Taylor, R.H., 1968
Tomich, 1969
Van der Werff, 1982
Vogl & Henrickson, 1971
Warner, 1960, 1963
Warshauer, 1977
Woodward, 1972
Yuncker, 1934

2b.Deer

Apple & Apple, 1972
Barrau & Devambez, 1957
Craine, 1975
Degener, 1968, 1972
Degener & Degener, 1969
Fosberg, 1972b
Lamoureux, 1968
Munro, 1970
Shikama, 1942
Spence & Montgomery, 1976
Steenis, 1972
Telfer, 1971
Titcomb, 1969a, 1969b
Walker, R.L., 1969

2c. Goats

Adsersen, 1976
Anonymous, 1978a, 1983a, 1987
Calvopina & Calvopina, 1980
Calvopina & DeVries, 1975
Campbell & Rudge, 1978
Carpenter, 1959
Christian & Tracy, 1980
Coblentz, 1978
Degener & Degener, 1961b
DeRoy, 1987
DeVries, 1977
DeVries & Black, 1983
DiSalvatore, 1981
Eibl-Eibesfeldt, 1960
Forbes, 1913a, 1913b
Gold, 1984
Grant, 1981
Hamann, 1978, 1979a, 1979b, 1981
Hickman, 1985
Holdgate & Wace, 1961
King, W., 1971
Kinnane, 1983
Kobayashi, 1973
Kramer, 1974
Lever, 1953
McHugh, 1986
McKinney, 1983, 1985
Mueller-Dombois & Spatz, 1972
Oberhansley, 1953
Paramonov, 1963
Pratt, 1973
Reeser, 1976
Sablan, 1976
Schofield, 1973b
Skottsberg, 1953a, 1954
Spatz & Mueller-Dombois, 1972b, 1973
St. John, 1979
Sykes, 1969
Thompson, 1965
Tomich, 1972
Vogl & Henrickson, 1971
Wardle, et al., 1978
Whistler, 1981a
Wiggins & Porter, 1971
Woolliams, 1974a
Yocom, 1967
Yuncker, 1934
Zimmerman, 1948, 1963

2d. Rabbits

Anonymous, 1942, 1979d, 1985c
Christophersen & Caum, 1931
Clapp & Wirtz, 1975
Coyne, 1983
Ely & Clapp, 1973
Lamoureux, 1963a, 1963b, 1964
Laycock, 1970
Richardson, 1963
Tomich, 1965
Tomich, et al., 1968
Warner, 1963
Watson, 1961

3. INTRODUCED, INDIGENOUS, AND ECONOMIC PLANTS

3a. Endangered and Threatened Plant Species

Amerson, Whistler & Schwaner, 1982a, 1982b
Anonymous, 1969a, 1978a, 1979e, 1980, 1981a, 1986a, 1986c
Ayensu & DeFilipps, 1978
Ayensu, et al., 1984
Bishop & Herbst, 1973
Bryan, 1971
Carr, Undated, 1982
Carr & Baker, 1977
Char, 1976
Char & Balakrishnan, 1979
Chilcott, 1986
Clapp, et al., 1977
Clark, 1986
Cribb, et al., 1985
D'Arcy, 1976
Degener & Degener, 1963, 1968, 1971c, 1971e, 1974c, 1976, 1977b
Degener, Degener & Hormann, 1969
Degeners & Sunadas, 1976
Devaney, et al., 1976
Doria, 1979
Drahos, 1974
Evans, et al., 1972
Fay, 1980, 1982
Fosberg, 1950
Fosberg & Herbst, 1975
Fosberg & Sachet, 1966, 1985
Funk, 1982
Gagne, B.H., 1982
Gagne, W.C., 1983
Gilmartin, 1970
Given, 1975
Gorman & Siwatibau, 1975
Green, 1979, 1985
Halle, 1980
Harney, 1983
Herbst, 1972b, 1976, 1977a, 1977b, 1984
Herbst & Fay, 1981
Heyerdahl, 1963
Hodel, 1980
Holt, 1981
IUCN - CMC, 1983a,1985,
Jenkins, D.W., 1975
Jenkins & Ayensu, 1975
Kimura & Nagata, 1980
Konishi, et al., 1979
Koopowitz & Kaye, 1983
Lamoureux, 1981, 1982
Lasseter & Gunn, 1979
Linney, 1982
Lucas & Synge, 1978
Lucas, S.A., 1961
Melville, 1979
Mohlenbrock, 1983
Moore, H.E., 1979
Moore, P.H., 1980
Moore & Uhl, 1984
Moore, P., Raulerson, L., et al., 1977
Munro, 1955a
Nagata, 1981, 1982
Obata, 1976, 1986
Obata & Smith, Undated
Ono, et al., 1986
Parman, 1975
Perlman, 1977, 1978, 1979
Powell, E., 1982, 1985
Pung, 1971
Ralph, 1978
Ralph, et al., 1980
Russ, 1932
Sachet, 1973
Schmid, 1981
Smithsonian Institution, 1975
Sneed, 1979
Stemmermann, et al., 1986
Stewart, 1973
St. John, 1959, 1979
St. John & Corn, 1981
Tagawa, 1976
Takeuchi, 1980, 1982
Tannowa, et al., 1976
Trust Territory of the Pacific Islands, 1976
Wallace, et al., 1973
Warshauer & Jacobi, 1982
Weimarck, 1984
Whistler, 1982
Wodzicki, 1973
Woolliams, 1974a, 1975b, 1976a, 1976c, 1978b, 1979, 1980, 1981a, 1983, 1985
Yoshida & Tannawa, 1976
Young & Popenoe, 1916

3b. Endemism and Endemic Plants

Anonymous, 1987
Bruhin, 1985
Bryan, 1973
Campon, 1982
Carlquist, 1965, 1970, 1974, 1982a
Carr, Robichaux & Kyhos, 1982
Carson, 1982
Creutz, 1966
Dahl, 1980, 1984c
Dawson, 1981
Degener, 1945, 1977
Degener & Degener, 1958, 1975a, 1975b
Dodd, 1976
Fosberg, 1948c, 1973c
Gerrish & Mueller-Dombois 1980
Glassman, 1957
Grant, 1981
Gustafson, 1979
Hall, E.O., 1839
Hamann, 1979c
Hamilton, T.H., et al., 1963
Hashimoto, 1977
Hawaii Volcanoes Nat'l. Park, 1974
Heyerdahl, 1963
Holing, 1987
Hurlimann, 1959b
Johnson & Raven, 1973
Kobayashi, 1973, 1974
Kores, 1979
Landgraf, 1973
LeBarron, 1971a
Leigh, et al., 1981
Moore, H.E., 1966, 1969
Mull, M.E., 1975a, 1975b
Munro, 1933, 1955b
Okutomi, et al., 1982
Parham, 1953b
Perry, 1974, 1984a
Pickard, 1980
Porter, 1979
Pung, 1971
Radovsky, et al., 1984
Rauh, 1981
Ronck, 1975
Schmid, 1981, 1982
Schofield, 1984
Serpell, et al., 1983
Skottsberg, 1953a, 1961
Smith, A.C., 1970
Sohmer, 1978
Stebbins, 1966
Steenis, 1964
St. John, 1946
Straatmans, 1964
Stuessy & Silva, 1983
Stuessy, et al., 1983
Svenson, 1963
Tannowa & Yoshida, 1975
Van Balgooy, 1971, 1973
Weaver, 1971
Whistler, 1982
Wichman, 1978
Wiggins, 1966
Woolliams, 1975c

3c. Economic Plants in General

Barrau, 1959b, 1967
Carter, 1940
Degener & Degener,1970, 1971b
Gosnell, 1976
Hashimoto, 1977
Jenkin & Foale, 1968
Lowry, 1973
Lucas, S.A., 1981
Massal & Barrau, 1956
McClelland, 1915
Niering, 1956
Perlman, 1977
Prescott-Allen & Prescott-Allen, 1982
Randall, 1973
Scheuer, 1961
Scowcroft & Sakai, 1984
Simmonds, 1956
Spate, 1979
Theobald, 1978
Vietmeyer, 1986b
Virot, 1951b
Waimea Arboretum, 1983
Walker, E.H., 1952
Wills, 1965

3d. Weeds and Other Alien Plants

Apfelbaum, Ludwig & Ludwig, 1983
Anonymous, 1986e
Barrau, 1958b, 1960a, 1983
Berger, 1975b
Catala, 1953
Chapman, V.J., 1975
Chock, 1963
Collins & Wells, 1983
Crosby & Hosaka, 1955
Degener, 1966, 1977
Degener & Degener, 1958
DeVries & Black, 1983
Doty, 1969
Eckhardt, 1972
Egler, 1939, 1942
Eliasson, 1982
Ellshoff, 1986
Elton, 1958
Fagerlund, 1947
Forbes, 1911
Fosberg, 1937b, 1948a, 1953b, 1955, 1957b, 1967, 1968b, 1979
Fosberg & Corwin, 1985
Fosberg & Sachet, 1962
Gagne, W.C., 1986
Gerrish & Mueller-Dombois 1980
Gilbert, 1977
Gosnell, 1976
Hamann, 1979b
Harris, 1962
Hart, 1975
Herbst, 1980
Heyligers, 1967
Higashino, et al., 1983
Holt, 1983a
Hosaka, 1936
Huguenin, 1974
Hunt, 1969
Jacobi, 1978
Judd, 1921, 1927d, 1940
Kastadalen, 1982
Kirch, 1982a
Knapp, 1975
Lamoureux, 1961
Lawesson, 1986
Lee, M.A.B., 1974
Loope & Stone, 1984
MacCaughey, 1918
McCombs, 1987
Merrill, 1940
Moldenke, 1968
Motooka, et al., 1967
Mune & Parham, 1956
Munro, G.C., 1957b
Myrhe, 1970
Nelson, 1960
Newhouse, 1980
Nishi, 1968
Obata, 1985a
Paine, 1934
Parham, 1953a, 1953c, 1953d
Parsons, 1945
Pickard, 1984
Porter, 1976
Powell, R.H., 1968
Price, 1936
Reboul, 1975
Richmond, 1965
Schofield, 1973c
School of Naval Admin., 1948
Setchell, 1923, 1926
Simmonds, 1934
Smathers & Gardner, 1979
Sorensen, 1977
State Dept. of Natural Resources, 1976
Stemmermann & Proby, 1978
St. John, 1954b, 1957a
Stone, 1967a
Svihla, 1936
Sykes, 1981
Takahashi & Ripperton, 1949
Thibault, 1975
Thorp, 1960c
Tuoc, 1983
Van der Werff, 1978
Vietmeyer, 1986b
Virot, 1956
Wace, 1960
Watts, 1960
Wester, 1978
Wester & Wood, 1977
Whistler, 1981b, 1983c
White, 1965
Whiteaker, 1983
Whitney, et al., 1939
Wiens, 1955, 1962
Wirawan, 1974
Wylie, 1924
Yee, 1984a
Yuncker, 1934, 1937, 1956

3e. Eucalyptus

Albert, 1986
Beighton, 1966
Gilmartin, 1970
LeBarron, 1962
McKinney, 1986
Pratt, 1973
Sachet, 1957
Shiva & Bandyopadhyay, 1983
Thorby, 1954
Zacharin, 1978

3f. Lantana

Anonymous, 1954
Bryan, 1949
Caum, 1936
Cruz, et al., 1986
Davis & Krauss, 1961
DeVries & Black, 1983
Fosberg, 1937a
Guillaumin, 1933
Hartley, 1963
Lamoureux, 1976a
MacDaniels, 1947
Parsons, 1945
State Dept. of Natural Resources, 1976
Svihla, 1936
Thaman, 1974a
Wylie, 1924
Yee, 1984a

3g. Ferns and Fernlands

Anonymous, 1979c
Barrau, 1959a
Croft, et al., 1976
Degener & Degener, 1966, 1971d
Fosberg, 1942
Giffin, 1977
Halle, 1980
Harrison, 1972
Judd, 1927d, 1937
Leigh, et al., 1981
Moore, P., 1974
Nelson & Hornibrook, 1962
Skottsberg, 1935, 1961
Stark, et al., 1958
St. John, 1954a
Van der Werff, 1978
Wagner, 1950, 1981
Whistler, 1980
Wodzicki, 1971

3h. Sandalwood

Anonymous, 1986b
Barrau, 1960b
Berger, 1974
Bryan, 1954
Davidson, 1956
Degener & Degener, 1973
Dodge, 1976
Douglas, B., 1971
Furnas, 1948
Guillaumin, 1970
Howe, 1984
Judd, 1927a, 1927c, 1936
Murthy, 1985
Powell, E., 1982
Rock, 1916
Serpell, et al., 1983
Shineberg, 1967
Skottsberg, 1953b, 1954
Snow & Waine, 1979
Stemmermann, 1980
St. John & Philipson, 1962
Wagner, 1985
Yuncker, 1934

3i. Medicinal Plants

Barrau, 1958a
Chand & Chand, 1980
Croft, et al., 1980
Grepin, 1976
Holdsworth, 1974
Johannes, 1985
Johnston, E.G., 1975
Nagata, 1971
Perry & Metzger, 1980
Rageau, 1973
Salcedo, 1970
Singh & Siwatibau, 1977
Singh, Y.N., 1986
Uhe, 1974
Virot, 1951b

4. HUMAN IMPACTS UPON SPECIES AND HABITATS

4a. Human Disturbance of Vegetation in General

Amerson & Shelton, 1976
Anonymous, 1958
Berger, 1977
Brewer, 1975
Brookfield & Glaser, 1975
Canfield, 1981
Clay, 1961
Cloud, et al., 1956
Cowan, 1976
Cribb, 1986
Dahl, 1984b
Decker, 1971
Degener, 1963
Degener & Degener, 1961c, 1974a, 1974b
Doan, Paseur & Fosberg, 1960
Dousset & Taillemite, Undated
Egler, 1956
Elliott & Hall, 1977
Falanruw, 1976a, 1976b
Fay, 1978
Force, 1981
Fosberg, 1951, 1953c, 1954b, 1957a, 1959d, 1960a, 1960b, 1960c, 1972a, 1975, 1977, 1983, 1984b, 1985
Fosberg & Sachet, 1969
Garnock-Jones, 1978
Gilbert, 1974
Green, 1969
Groube, 1971
Guillaumin, 1953b
Halle, F., 1978
Hamann, 1981
Havas, 1985
Heyerdahl, 1940
Holzner, et al., 1983
Hosokawa, 1967
Hughes & Hope, 1979
Hurlimann, 1959a
Jenkins, J.T., 1948
Johnson, et al., 1960
Kemf, 1985
King, J., 1978
King, W., 1971
Kirch, 1982c
Knapp, 1975
Kramer, 1973, 1983
Kurrus, 1985
Little, H.P., 1982
MacDaniels, 1952
Mangenot, 1963
Mann, 1866
Marshall & Medway, 1976
Marshall, C., 1949a
Marshall, D., 1961
McIntire, 1960
McKinney, 1985
McMichael & Talbot, 1970
Moore, 1983
Murdock, 1963
Muzik, 1985
Newell, 1986
Niering, 1961, 1963
Nisbet, 1976
Patterson, 1986
Petard, 1948
Randall & Holloman, 1974
Randall & Tsuda, 1974
Rappaport, 1963
Reed, 1952
Rinke, 1986
Robbins, 1972
Salvat & Richard, 1985
Sanders, et al., 1982
Schafer, 1977
Schmid, 1981
Schofield, 1973a
Shallenberger, 1975, 1982
Siegel, 1973
Skottsberg, 1920-1956, 1935, 1957
Smith, C.W., 1971
Smith, S.V., 1978
Sparre, 1973
Stark, 1958
St. John, 1957b, 1977
St. John & Fosberg, 1937
Stoddart, 1968a, 1968b, 1969
Stone, 1976
Summerhays, 1984
Talbot & Holdren, 1985
Terrell, 1976
Thorne, 1965
U.S. Army, 1955
Veillon, 1971
Virot, 1951a, 1954
Walsh, 1976
Warner, 1961a, 1961b
Weber, et al., 1977
Whistler, 1980, 1983a, 1983b
Wiens, 1955

Wodzicki & Laird, 1970
Wright, 1946
Yuncker, 1945

4b. Economic Development

Acosta-Solis, 1966
Anonymous, 1967, 1983b, 1984a
Baines, 1984
Barrau, 1981
Bunge & Cooke, 1984
Carson, 1982b
Chamberlain, 1972
Chave & Maragos, 1973
Cheatham, 1975
Cieply, 1983
Colwell, 1946
Dahl, 1984a
Degener & Degener, 1984
Faulkner, 1981
Fernald, 1981
Fosberg, 1984a
Fosberg & Sachet, 1983a
Fosberg, Sachet & Stoddart, 1983
Frome, 1986
Gold, 1985
Gormley, 1984
Havas, 1985b
Heine, 1984
Herbst, 1976
Jenkin & Foale, 1968
Juvik & Juvik, 1984
Karasik, 1984
Kluge, 1986
Koford, 1966
Lal, 1984
Levathes, 1983
Mackensen & Hinrichsen, 1984
Mason, 1979
McKinney, 1986
Moverley, 1953
Newell, 1986
Norris, 1986
Oliver, 1951
Ridgeway, 1983
Salvat, 1985
Seiden, 1985
Serpell, 1983
Templet, 1986
Trust Territory of the Pacific Islands, 1972
Umpingco, 1975
Van der Poel, 1975

4c. Population Pressure

Campbell, 1952
Connell, 1984, 1986
Coulter, 1931
Falanruw, 1985
Gourou, 1963
Heine, 1984
Kluge, 1986
Lewin, 1978
Menard, 1982
Perez, 1975
Sabath, 1977
Schultze-Motel, 1974
Smith, S.V., 1978
Straatmans, 1964
Thaman, 1974b
Ward, 1965
Wiens, 1962

4d. Agriculture

Budowski, 1972
Christensen, C.C., 1982
Christensen & Kirch, 1981
Clapp & Sibley, 1971
Cumberland, 1949
DiCastri & Glaser, 1980
Fosberg, 1973a
Gilbert, 1974
Hartley, 1963
Heyligers, 1967
Howard, 1962
Kira, et al., 1962
Kirch, 1982b
Kramer, 1973
Langlois, 1976
Lever, 1964
Matsue, 1932
Maxwell, 1985
McClelland, 1915
McIntire, 1961
McQueen, 1983
Milne & Steward, 1967
Nishi, 1968
Parsons, 1945
Porteous, 1978

Sachet, 1983a, 1983b, 1983c, 1983d
Schofield, 1973c
Siwatibau, 1984
Taylor, J.L., 1951
Thaman, 1974b, 1976
Ward, 1965
Watters, 1960
Westendorp, 1961
Wiggins & Porter, 1971
Wodzicki, 1971
Womersley, 1974
Yen, 1975

4e. Soil Erosion

Carlson, 1954
Coulter, 1940
Cumberland, 1953
D'Espeissis, 1953
Dugain, 1953
Egler, 1941
Fosberg, 1973a
Garnock-Jones, 1978
Gourou, 1963
Graf, 1972
Holdgate & Wace, 1961
Josiah, 1983
Lee, K.E., 1969
McCracken, 1953
McHugh, 1986
Moore & McMakin, 1979
Morat & Veillon, 1985
Mueller-Dombois, 1973b
Munro, 1929
Tercinier, 1974
Webster, 1951
Yuncker, 1956

4f. Deforestation

Anonymous, 1984b, 1985a, 1985b
Bayliss-Smith, 1978
Berger, 1975a
Browne, 1987
Bryan, 1929
Caufield, 1985
Clarke, 1986
Cook, 1937
Cumberland, 1963
Donaghho, 1970
E, 1938
Flanders, 1985
Gosnell, 1976
Gourou, 1963
Gradstein & Weber, 1982
Heyerdahl, 1968
Holden, 1985
Hosmer, 1910
Howarth, 1972, 1973
Johnston, W.B., 1959
Judd, 1927b, 1927c
Kalkman, 1983
Kawamura, et al., 1940
Kenchington, 1985
Kirch, 1980
Linklater, 1974
Lyon, 1918
Marden, 1957
Morat & Veillon, 1985
Moverley, 1953
Myers, 1980
Ralph, 1982
Ranjitsinh, 1979
Rao & Chandrasekharan, 1983
Routley & Routley, 1980
Schubert, 1961
St. John, 1966
Strauss, 1978
Tenney, 1909
Tuyama, 1953
U.S. Civil Admin. Ryukyu Is., 1953
Van Tilburg, 1987
Warner, 1961
Yates, 1984

4g. Forestry

Animal Species Advisory Commission, State of Hawaii, 1974
Berger, 1966
Bryan, 1947
Buck, 1984
Carlson, 1973
Chapline, 1961
Cheatham, 1968
D'Espeissis, 1953
Donaghho, 1970
Frome, 1986
Fullaway, 1975

Gilmartin, 1970
Hall, W.L., 1904
Halle, F., 1978
Hamilton, L.S., 1983
Hatheway, 1952
Hobdy, 1976
Holt, 1983b
Hoyle, 1978
Jacobi, 1978
Judd, 1927d, 1940
Knibb, 1984
Kroon, 1953
Lamoureux, 1976b
LeBarron, 1966, 1970, 1971a
Little, E.L., 1969
Lyon, 1919, 1922, 1927, 1929
Marshall, C., 1949b, 1953, 1961
Merlin, 1985
Mueller-Dombois, 1980, 1981, 1983a, 1984a, 1984c
Munro, 1957b
Nelson, 1964, 1967, 1971
Obata, 1985b
Pardo, 1984
Pickford, 1962
Pung, 1971
Richmond, 1965
Routley & Routley, 1980
Scowcroft, 1971, 1983
Spence & Montgomery, 1976
Thorby, 1954
Tuttle, 1986
Vietmeyer, 1986
Walker, C.M., 1971
Walker, F.S., 1962
Warner, 1960
White, 1965
Whitesell, 1964, 1974
Whitesell & Landgraf, 1966
Whitmore, 1966
Yuncker, 1934

4h. Mining

Anonymous, 1966, 1969b
Aubert de la Rue, 1958
Doumenge, 1963
Holthus, 1985
Lucas, G., 1980
Manner, et al., 1984
McMakin, 1977
Moomaw & Takahashi, 1960
Parrat, 1971
Wentworth, et al., 1955
Williams & Macdonald, 1985
Younge & Moomaw, 1960

4i. Nuclear Testing

Anderson, A., 1979
Anderson, J.A., 1972
Biddulph & Cory, 1952
Blumberg & Conard, 1961
Chevalier, et al., 1968
Danielsson, 1984
Doran, 1959
Ellis, 1986
Fosberg, 1959a
Hess, 1962
Libby, 1969
Marsh, 1979
Mid-Pacific Marine Lab., 1975
Nolan, et al., 1975
Palumbo, 1962
Street, 1960
Taylor, W.R., 1950
Weller, 1981

4j. Tourism

Anonymous, 1985d
Boutilier, 1981
DeGroot, 1983
Fullard-Leo, 1985
Gormley, 1984
Grahem, 1987
Heacox, 1984
Kluge, 1969b
Lindsey, 1986
McGorum, 1975
Perez, 1975
Porcher & Dupuy, 1985
Seiden, 1985
Tindle, 1983
Umpingco, 1975
Watson-Gegeo, 1982
Wills, 1965

4k. World War II

Amerson, 1971, 1973
Baker, R.H., 1946
Bartley, 1954
Bryan, 1982
Burcham, 1948
Chamberlain, 1972
Colwell, 1948
Corwin, et al., 1957
Coulter, 1946
Dawson, 1959
Degener & Gillaspy, 1955
Doan, et al., 1960
Doe, 1971
Doran, 1959
Fischer & Fischer, 1957
Fisher, 1949, 1966
Fosberg, 1949, 1953b, 1956b, 1957b, 1959b, 1959d
Heinl, 1947
Heinl & Crown, 1954
Hoffman, 1950, 1951
Hough, 1947, 1950
Hough & Crown, 1952
Keck, 1957
Kluge, 1969a, 1969c
Kuroda, 1954
Lodge, 1954
Moore, H.E., 1969
Moore, W.R., 1945
Nanyo Cho, 1932
Office of the Chief Engineer, 1951
Polansky, 1966
Rogers, 1975
Sakagami, 1961
Sampson, 1968
Sneed, 1983
Spoehr, 1954
Stark, et al., 1958
Steinberg, 1978
Stemmermann & Proby, 1978
St. John, 1960
Stockman, 1947
Stoddart, 1975
Stone, 1963
Taylor, W.R., 1950
Thorp, 1960a, 1960b
Trust Territory of the Pacific Islands, 1972
U.S. Army, 1956
U.S. Navy, 1946
U.S. War Department, 1946
Walker, E.H., 1953, 1957
Wiens, 1957
Woolliams, 1974a

5. CONSERVATION ACTIVITIES AND VALUES

5a. Conservation Studies and Problems

Coolidge, 1948
Costin & Groves, 1973
Dahl, 1980, 1985
Davis, S.D., et al., 1986
Degener & Degener, 1977a
Dorst, et al., 1972
Doty, 1973
Douglas, G., 1970
Dybas, 1948
Elliott, 1973
Falanruw, 1971
Fosberg, 1953a, 1956a, 1959c, 1973b, 1973d
Gillett, 1972
Guillaumin, 1953b
Heywood, 1979
Holdgate & Nicholson, 1967
Holthus, 1985
Hosokawa, 1973
Hurlimann, 1953
IUCN (CMC), 1983b, 1986b
Jacobs & deBoo, 1982
Johnson, S.P., 1972
Juvik & Juvik, 1984
King, W.B., 1973
Kochi, 1971
Kramer, 1974
Lamb & Gressitt, 1976
Lamoureux, 1973a, 1973b
Lawcock, 1982
Liem, 1977
Linge, 1983
Maragos & Elliott, 1985
Marshall, A.G., 1973
McMichael & Talbot, 1970
Munro, 1952b, 1952c, 1957a
Nicholson, 1969
Nicholson & Douglas, 1970
Nicholson & Eldredge, 1970
Numata, 1969
Oberhansley, 1953
Okutomi, et al., 1982

Perez, 1975
Perry, 1969
Sachet, 1954
Schofield, 1981
Serpell, et al., 1983
Skottsberg, 1940, 1953b, 1961, 1962
Smith, N., 1977
Sorensen, 1974
Souder, 1968
Steenis, 1965
Stemmermann, et al., 1986
Stoddart, 1971, 1976
Tabata, 1980
Talbot, 1969
Tokyo Metropolitan Government, 1969-1970
Turner, et al., 1968
Van Balgooy, 1973
Van der Werff, 1979
Virot, 1954
Wallis, 1961
Warner, 1968
Weber, D., 1971
Weimarck, 1984
Wells, 1985
Wenkham, 1967a
Whitmore, 1976, 1980
Wilson, 1976
Wodzicki, 1970, 1981

5b. Ecosystems

Byrne, 1979
Carew-Reid, 1984
Carlquist, 1974
Chapman, M.D., 1985
Chapman, V.J., 1969
Christensen, B., 1983
Corner, 1972
Dahl, 1980
Dahl & Baumgart, 1982
Diamond, 1982
Eyde & Olson, 1983
Fosberg, 1948b, 1954a,1963b, 1966, 1968a, 1971, 1972a, 1973b
Fosberg & Sachet, 1983b
Gagne, W.C., 1975
Gilpin & Diamond, 1980
Gon, 1987
Grady, 1986
Gustafson, 1979
Herbst, 1972a
Hertlein, 1963
Hosokawa, 1967
Howarth, 1972, 1973
Johnson, S.P., 1972
Judd, 1922
Kay, 1972
Keast, 1966
Kenchington, 1985
Kirkpatrick & Hassall, 1981
Kuschel, 1963
Levine, 1984
Matthiessen & Wenkham, 1970
Mueller-Dombois, 1967, 1972, 1973c, 1981, 1983a, 1983b, 1984a, 1984b, 1984c
Mull, M.E., 1977
Murdock, 1963
Newhouse, 1979
Perry, 1984b
Peterson, R.T., 1967
Pickard, 1973
Prior & Stanhope, 1980
Rappaport, 1963
Raynal, 1979
Robyns & Lamb, 1939
Sachet & Fosberg, 1983
Salvat, 1976
Spatz & Mueller-Dombois, 1972a
Stoddart, 1965, 1967
U.S. Dept. of the Interior, 1968, 1970
Vogl, 1971
Wace, 1978
Wace & Holdgate, 1976
Zucker, 1985

5c. Nature Reserves

Acosta-Solis, 1963
Amerson, Clapp & Wirtz, 1974
Anonymous, 1982, 1985e, 1985f
Bowman, 1963
Corporacion Nacional Forestal, 1976a, 1976b
Cranwell, 1984
Curry-Lindahl, 1980
Dahl, 1980
Decker, 1975
Frome, 1986
Gilpin & Diamond, 1980

Gold, 1985
Guillaumin, 1953a
Hawaii Volcanoes National Park, 1974
Hosmer, 1910
Hurlimann, 1959b, 1960
IUCN (CMC), 1983b
IUCN (CNPPA), 1982a, 1982b
Jacobi, 1981
Loope & Stone, 1984
Mack, 1975
Marshall, A.G., 1973
McKinney, 1983
Mueller-Dombois, 1973a
Mull, M.E., 1975b
Oberhansley, 1953
Peterson, B., 1964
Pulea, 1984
Pung, 1971
Reeser, 1976
Root, 1952
Singh, B., 1982
Skottsberg, 1961
Smathers, 1969
Stine, 1986
Taketa, 1987
Tomich, 1972
Trotman, 1979
Villa & Ponce, 1982
Warshauer, 1977
Wenkham, 1967b, 1971
Whistler 1976, 1978
Whiteaker, 1983
Whitesell, 1972

5d. Botanical Gardens

Anonymous, 1973, 1977, 1979a, 1979b, 1981b
Baker & Allen, 1977
Christensen, C., 1979
Costa, 1978
Degener & Degener, 1977c
Dworsky, 1986
Gagne, W.C., 1986
Gardiner, 1979
Hirano, 1973
Hirano & Nagata, 1972
IUCN - CMC, 1983a, 1983b
Koopowitz & Kaye, 1983
Lucas, S.A., 1981
Moir, 1971
Obata, 1976
Perlman, 1977, 1979
Shimozono & Iwatsuki, 1986
Sneed, 1983
Tannowa & Yoshida, 1975
Theobald, 1976, 1980
Waimea Arboretum, 1983
Weimarck, 1984
Wichman, 1978
Woolliams, 1972a, 1972b, 1974b, 1975a, 1975b, 1976b, 1976c, 1978a, 1981b, 1982,
Woolliams, et al., 1980a, 1980b
Yee, 1984b

5e. Ethics of Conservation

Abbott, 1975
Iltis, 1967
McHarg, 1971
Sears, 1959
Van der Poel, 1975

GEOGRAPHICAL INDEX

ADMIRALTY IS.

Corner, 1972

AILINGINAE; see also Marshall Is.

Fosberg, 1959a

AITUTAKI; see also Cook Is.

Stoddart, 1975

ALAMAGAN; see also Micronesia

Fosberg, 1973b

ALCEDO; see also Galapagos Is.

Van der Werff, 1982

ALEIPATA IS.;see also Samoa, Western

Whistler, 1983b

ANATAHAN; see also Marianas Is.

Sablan, 1976

ANGAUR; see also Palau Is.; Micronesia

Fosberg, 1957b
Wentworth, et al., 1955

ARUTA; see also Polynesia

Canby, 1984

ASUNCION; see also Marianas Is.

Anonymous, 1985e, 1985f

ATAFU; see also Tokelau Is.

Whistler, 1981b

AUCKLAND IS.

Campbell & Rudge, 1978
Wardle, et al., 1978

BABELTHUAP

Cheatham, 1968

BAILEY; see also Bonin Is.

Tuyama, 1953

BALTRA; see also Galapagos Is.

Hamann, 1981

BANABA; see also Gilbert Is.

Strong, 1976
Williams & Macdonald, 1985

BARRINGTON; see also Galapagos Is.

Eibl-Eibesfeldt, 1860

BATIKI; see also Fiji Is.

Bayliss-Smith, 1978

BIKINI; see also Marshall Is.

Ellis, 1986
Libby, 1969
Taylor, W.R., 1950

BISMARCK IS.

Jacobs & DeBoo, 1982
Lamb & Gressitt, 1976

BONIN IS.

Degener & Degener, 1971a
Hashimoto, 1977
Nicholson & Douglas, 1970
Numata, 1969
Ono, 1985
Ono, et al., 1986
Sampson, 1968
Shimozono & Iwatsuki, 1986
Tannowa & Yoshida, 1975
Tannowa, et al., 1976
Tokyo Metropolitan Government, 1969-1970
Tuyama, 1953
Woolliams, 1974a, 1975c, 1976a, 1978b, 1983
Yoshida & Tannowa, 1976

BORABORA; see also Society Is.

Keast, 1966

BOUGAINVILLE; see also Solomon Is.

Cribb, 1986
Heyligers, 1967

BUKA; see also Solomon Is.

Heyligers, 1967

CANTON; see also Phoenix Is.

Degener & Degener, 1958, 1959, 1974b
Degener & Gillaspy, 1955
McIntire, 1960
Stoddart, 1968b

CAROLINE IS.

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IUCN - CMC, 1986b
Newell, 1986
Stemmermann & Proby, 1978

CHARLES; see also Galapagos Is.

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FENUA URA

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IUCN - CMC, 1986b
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Thompson, 1965
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Wylie, 1924

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Herbst, 1980

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Niering, 1961

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Acosta-Solis, 1963, 1966
Adsersen, 1976

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Black, 1976
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Peterson, R.T., 1967
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Skottsberg, 1953b
Stebbins, 1966
Strong, 1976
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Wills, 1965

HAWAII (Island of); see also Hawaiian Islands

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Char, 1976
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Degener & Degener,1968, 1977b, 1984
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Fosberg, 1972b, 1973a
Frome, 1986
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Jacobi, 1978
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Landgraf, 1973
Lassetter & Gunn, 1979
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Long, 1960
McIntire, 1961
McKinney, 1983
Mitchell, 1981
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Mueller-Dombois & Krajina, 1968
Mueller-Dombois & Spatz, 1972
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Oberhansley, 1953
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Richmond, 1965
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Scowcroft & Sakai, 1984
Smathers, 1969
Smathers & Gardner, 1979
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Spatz & Mueller-Dombois, 1972a, 1972b, 1973
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Stine, 1986
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Berger, 1966, 1974, 1975a, 1975b, 1977
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Bryan, L.W., 1947, 1971
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Carlquist, 1970, 1974, 1982a, 1982b
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Degener & Degener, 1961a, 1961b, 1961c, 1963, 1966, 1969, 1970, 1971b, 1971c, 1971d, 1971e, 1972, 1973, 1974a, 1974c, 1975a, 1975b, 1976, 1977a, 1977b, 1977c
Doty, 1969
Dutton, 1884
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Elton, 1958
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Forbes, 1911, 1913a, 1913b
Force, 1981
Fosberg, 1937a, 1937b, 1942, 1948a, 1948c, 1954a, 1963b, 1971, 1975
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Gagne, W.C., 1975, 1983, 1986
Gardiner, 1979
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Hart, 1975
Herbst, 1972a, 1972b,1977a, 1977b, 1980, 1984
Hirano, 1973
Hirano & Nagata, 1972
Hobdy, 1976
Holing, 1987
Holt, 1981, 1983a, 1983b
Howard, 1962
Howarth, 1972, 1973
IUCN - CMC, 1983a, 1983b, 1985, 1986a, 1986b
Jenkins, 1975
Jenkins & Ayensu, 1975
Judd, 1916, 1921, 1922, 1927a, 1927b, 1927c, 1927d, 1936, 1937, 1940
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Keast, 1966
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Kirch, 1982a, 1982b, 1982c
Knapp, 1975
Konishi, et al., 1979
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Lamoureux, 1961, 1963a, 1963b, 1964, 1973a, 1973b, 1976a, 1976b, 1981, 1982
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Levine, 1984
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MacCaughey, 1918, 1918-1919
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Mann, 1866
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McGorum, 1975
McIntire, 1961
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1984a, 1984b
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Nisbet, 1976
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Obata, 1985
Obata & Smith, Undated
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Powell, R.H., 1968
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Ralph, et al., 1980
Rauh, 1981
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Sohmer, 1978
Sorensen, 1977
Squire, 1984
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Wenkham, 1967a
Wester, 1978
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Woodward, 1972
Woolliams, 1972a, 1972b, 1974b, 1975a, 1975b, 1976b, 1976c, 1978a, 1979, 1981b, 1982
Woolliams, Degener & Degener, 1980a, 1980b
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Yee, 1984a, 1984b
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Yuncker, 1934, 1937

HENDERSON; see also Tuamotu Is.

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Fosberg, 1959c, 1984
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Fosberg, Sachet & Stoddart, 1983
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IRIOMOTE; see also Ryukyu Is.

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ISLE OF PINES; see also New Caledonia

Shineberg, 1967

IWO JIMA

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JOHNSTON

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JUAN FERNANDEZ IS.

Anonymous, 1968, 1987
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Lucas, G.L. & H. Synge, 1978
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Peterson, 1964
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Stuessy & Silva, 1983

KAHOOLAWE; see also Hawaiian Is.

Bryan, E.H., 1931
Forbes, 1913a
Gourou, 1963
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Kirch, 1982b
Kurrus, 1985
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Whitesell, 1974

KAPINGAMARANGI; see also Caroline Is.

Niering, 1956, 1963
Wiens, 1955

KAUAI; see also Hawaiian Is.

Anonymous, 1977, 1978b, 1985d
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Gosnell, 1976
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McIntire, 1961
McKinney, 1986
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Stewart, 1973
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Wenkham, 1967b
Wichman, 1978

KAULA; see also Leeward Hawaiian Is. & Hawaiian Is.

Caum, 1936

KERMADEC IS.

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Sykes, 1969

KOLOMBANGARA; see also Solomon Is.

Hunt, 1969
IUCN - CNPPA, 1982

KOSRAE; see also Caroline Is.

Buck, 1984

KURE; see also Leeward Hawaiian Is. & Hawaiian Is.

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Lamoureux, 1961
Woodward, 1972

KUSAIE; see also Caroline Is.

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Hosokawa, 1973

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Wiens, 1957

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LANAI; see also Hawaiian Is.

Anonymous, 1986b
Degener, 1963
Degener & Degener, 1971e
Fosberg, 1936, 1959c
Gourou, 1963
Munro, 1929, 1952a, 1955a, 1957b, 1970
Seiden, 1985
Spence & Montgomery, 1976

LAYSAN; see also Leeward Hawaiian Is. & Hawaiian Is.

Anonymous, 1942, 1985c
Christophersen & Caum, 1931
Cowan, 1976
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LEEWARD HAWAIIAN IS.

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Woodward, 1972

LEHUA; see also Hawaiian Is.

Caum, 1936
Richardson, 1963
Watson, 1961

LINE IS.

Clapp & Sibly, 1971

LISIANSKI; see also Leeward Hawaiian Is. & Hawaiian Is.

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Watson, 1961

LORD HOWE I.

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Green, 1979
Keast, 1966
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Lucas, G.L. & H. Synge, 1978
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Pickard, 1973, 1980, 1984
Smith, N., 1977

MAGO; see also Fiji Is.

Thompson, 1965

MAJURO; see also Marshall Is.

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Wiens, 1957

MAKATEA; see also Tuamotu Is.

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Williams & Macdonald, 1985

MAKIN

U.S. War Department, 1946

MALEKULA; see also New Hebrides

Marshall & Lord Medway, 1976

MANANA; see also Hawaiian Is.

Tomich, 1965
Tomich, et al., 1968
Watson, 1961

MANGAREVA

Cook, 1937
Huguenin, 1974
Kirch, 1982b
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MANUA IS.;see also Samoa, American

Yuncker, 1945

MARCUS

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Satagami, 1961

MARIANAS IS.

Anonymous, 1985e, 1985f
Doan, et al., 1960
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MARQUESAS IS.

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Clarke, 1986
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Lucas, G.L. & H. Synge, 1978
Schafer, 1977

MARSHALL IS.

Chamberlain, 1972
Doe, 1971
Ellis, 1986
Fosberg, 1953c, 1955, 1956b, 1959a
Heine, 1984
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Stone, 1963
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Wiens, 1957

MASAFUERA; see also Juan Fernandez Is.

Skottsberg, 1954, 1957, 1962

MASATIERRA; see also Juan Fernandez Is.

Skottsberg, 1935, 1961, 1962

MAUG; see also Marianas Is.

Anonymous, 1985e, 1985f
Ronck, 1975

MAUI; see also Hawaiian Is.

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Jacobi, 1981
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Kobayashi, 1973, 1974
Lamoureux, 1976a
Landgraf, 1973
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Peterson, 1976
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Svihla, 1936
Vogl, 1971
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Weaver, 1971
Whiteaker, 1983
Yocum, 1967

MELANESIA

Davis, S.D., et al., 1986
Holdsworth, 1974
Howe, 1984
Keast, 1966
Myers, 1980
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Sachet, 1957
Terrell, 1976
Whitmore, 1980

MICRONESIA

Anonymous, 1958
Baker, 1946
Brewer, 1975
Cheatham, 1975
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Davis, S.D., et al., 1986
Dybas, 1948
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Fosberg, 1951, 1953a, 1956b, 1957b, 1960a, 1968b, 1973b, 1984
Fullaway, 1975
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Johnston, 1975
Nanyo Cho, 1932
Nishi, 1968
Oliver, 1951
Otobed, 1975
Owen, 1979
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Rogers, 1975
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Steenis, 1965
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Wilson, 1976

MIDWAY; see also Leeward Hawaiian Is. & Hawaiian Is.

Apfelbaum, et al., 1983
Fisher, 1949, 1966
Thorp, 1960b

MINAMIJIMA; see also Bonin Is.

Woolliams, 1974a,1975c

MIYAKO ARCHIPELAGO; see also Ryukyu Is.

Doan, et al., 1960
Fosberg, 1960b

MOEN; see also Caroline Is.

Newell, 1986

MOHOTANI; see also Marquesas Is.

Sachet, et al., 1975

MOKOLI'I; see also Hawaiian Is.

Herbst & Fay, 1981

MOLOKAI; see also Hawaiian Islands

Carlson, 1954
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Forbes, 1913a
Fosberg, 1967
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Gormley, 1984
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Pratt, 1970
Richardson, 1949
Titcomb, 1969b

MOLOKINI; see also Hawaiian Is.

Watson, 1961

MOOREA; see also Society Is.

Petard, 1948

MOPELIA; see also Society Is.

Sachet, 1983d

MUKOJIMA; see also Bonin Is.

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MURUROA; see also Tuamotu Is.

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NADI; see also Fiji Is.

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NANANU IS.; see also Fiji Is.

Thompson, 1965

NARBOROUGH; see Fernandina

NAURU

Manner, et al., 1984
Williams & Macdonald, 1985

NEW BRITAIN; see also Bismarck Is.

Hough & Crown, 1952
Liem, 1977
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Sachet, 1957
White, 1965
Womersley, 1974

NEW CALEDONIA; see also Melanesia

Anonymous, 1966
Aubert de la Rue, 1958
Barrau, 1958a, 1958b, 1981, 1983
Barrau & Devambez, 1957
Carlquist, 1974
Catala, 1953
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Green, 1969
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Hurlimann, 1953, 1959a, 1959b, 1960
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Moore, H.E., 1979
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Parrat, 1971
Parsons, 1945
Rageau, 1973
Sachet, 1957
Schmid, 1981, 1982
Skottsberg, 1953c
Smith, A.C., 1971
Strong, 1976
Theobald, 1978
Thorne, 1965
Veillon, 1971
Vietmeyer, 1986
Virot, 1951a, 1952a, 1954, 1956

NEW GEORGIA; see also Solomon Is.

Kalkman, 1983

NEW HEBRIDES; see also Melanesia

Corner, 1972
Davidson, 1956
Green, 1979
Hoyle, 1978
Marshall, 1973
Massal & Barrau, 1956
Sachet, 1957
Theobald, 1978

NEW IRELAND

Simmonds, 1956

NIHOA; see also Leeward Hawaiian Is. & Hawaiian Is.

Clapp, et al., 1977
Gagne, 1983

NIIHAU; see also Hawaiian Is.

Caum, 1936
Forbes, 1913b
Gouron, 1963
Menard, 1982
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NIUATOPUTAPU; see also Tonga Is.

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NIUE

Westendorp, 1961
Wodzicki, 1971

NORFOLK I.

Anonymous, 1967
Ayensu, et al., 1984
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Turner, et al., 1968
Watson, 1961

NUKUHIVA; see also Marquesas Is.

Gillett, 1972

OAHU; see also Hawaiian Is.

Albert, 1986
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Degener & Degener, 1963, 1971c
Devaney, et al., 1976
Egler, 1939, 1942, 1947
Evans, et al., 1972
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Gerrish & Mueller-Dombois, 1980
Gourou, 1963
Grady, 1986
Hall, 1839
Hatheway, 1952
Herbst, 1976
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Judd, 1927b
Kurrus, 1985
Lyon, 1929
McIntire, 1961
Mueller-Dombois, 1973d
Obata, 1976, 1985a
Siegel, 1973
Smith, C.W., 1971
Stemmermann, et al., 1986
St. John, 1947, 1966
Svihla, 1936
Tabata, 1980
Tenney, 1909
Vietmeyer, 1986b
Wirawan, 1974
Woolliams, 1980
Yuncker, 1937

OCEAN I.; see Banaba

OGASAWARA IS.; see Bonin Is.

OKINAWA; see also Ryukyu Is.

Walker, 1952, 1953, 1957

PAGAN; see also Marianas Is.

Corwin, et al., 1957
Fosberg & Corwin, 1985

PAGO PAGO; see also Samoa, American

Graf, 1972

PALAU IS.; see also Caroline Is.

Anonymous, 1969b
Burcham, 1948
Canfield, 1981
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Faulkner, 1981
Force, 1981
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Kochi, 1971
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